AD A030178

No Security Objection to Open Publication (AS AMENDED)
FEB 4 1975
Office of the Chief of Naval Operations
Dept. of the Navy

14 G1063

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9 Engineering Report, 26 Jan - 20 Apr 73

6 VOLTAGE PROBE ANTENNA (VPA) DESIGN
5 kHz to 500 MHz.

10 Gary Keeth
Howard Hochman
William Buchele

11 1973

Report Period
26 January 1973 to 20 April 1973

12 64p.

15 Contract
N00123-73-C-1305

GTE SYLVANIA INCORPORATED
Electronic Systems Group, Western Division
P. O. Box 205
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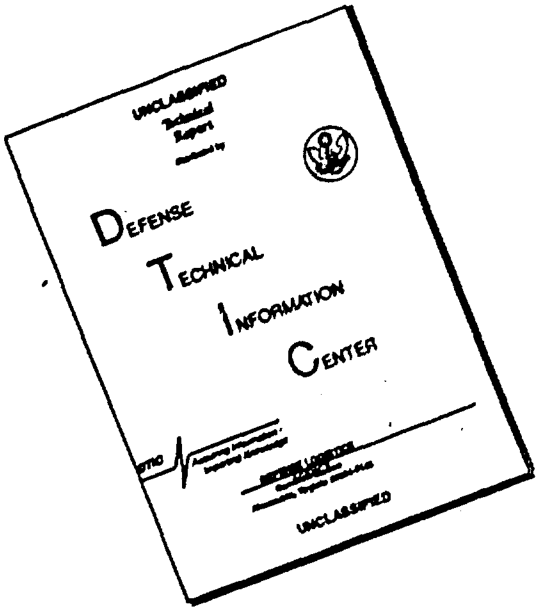

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Section 1

GENERAL DESCRIPTION

The objective of the overall development of the voltage probe antenna (VPA) was [redacted]

This report describes the engineering processes involved in the development of the latest version of the VPA.

"...to produce a miniature, mast mounted, omni-directional antenna that would operate over the band from 5 kHz to 500 MHz for communications reception. In addition, it was desired to optimize the antenna at 150 MHz and 400 MHz."

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Section 2

VOLTAGE PROBE ANTENNA, AMPLIFIER DESIGN

2.1 GENERAL DESCRIPTION.

The voltage probe antenna (VPA) is a low-noise amplifier designed to provide an impedance match to an electrically short antenna over a very wide frequency range. The characteristics of such an antenna requires that the amplifier have very high input impedance at very low frequencies and approximately 50-ohm input impedance above 100 MHz. The amplifier provides approximately 11 dB gain between 5 kHz and 500 MHz in a 50-ohm system. It can be seen that the power gain of the high impedance amplifier will be much greater than 11 dB when inserted between a high-impedance source and a 50-ohm load. This is the condition that exists at low frequencies when the antenna impedance is high.

2.2 CIRCUIT DESCRIPTION.

The amplifier consists of two active stages; the first stage consists of a low-noise field-effect transistor used for active impedance matching, and the second stage consists of a low-noise microwave integrated circuit that provides actual voltage gain. (See Figure 2-1.)

The field-effect transistor is operated in a cource-follower configuration with an additional gate-to-source capacitor C2 added to alter the input impedance characteristics and to improve high-frequency performance. (See Figure 2-2.) At low frequencies where the gate and source of the transistor have an in-phase voltage of nearly equal magnitude, capacitor C2 essentially disappears from the circuit as very little voltage appears across it. This provides a very high impedance at low frequencies that approaches 1.5 megohms shunted by 4 pF.

At high frequencies where the voltage on the source of the transistor begins dropping and the phase shift becomes important, signal voltage begins to develop across capacitor C2. This provides a signal path around the first-stage transistor Q1. As the frequency goes progressively higher, the impedence of capacitor C2 drops quite

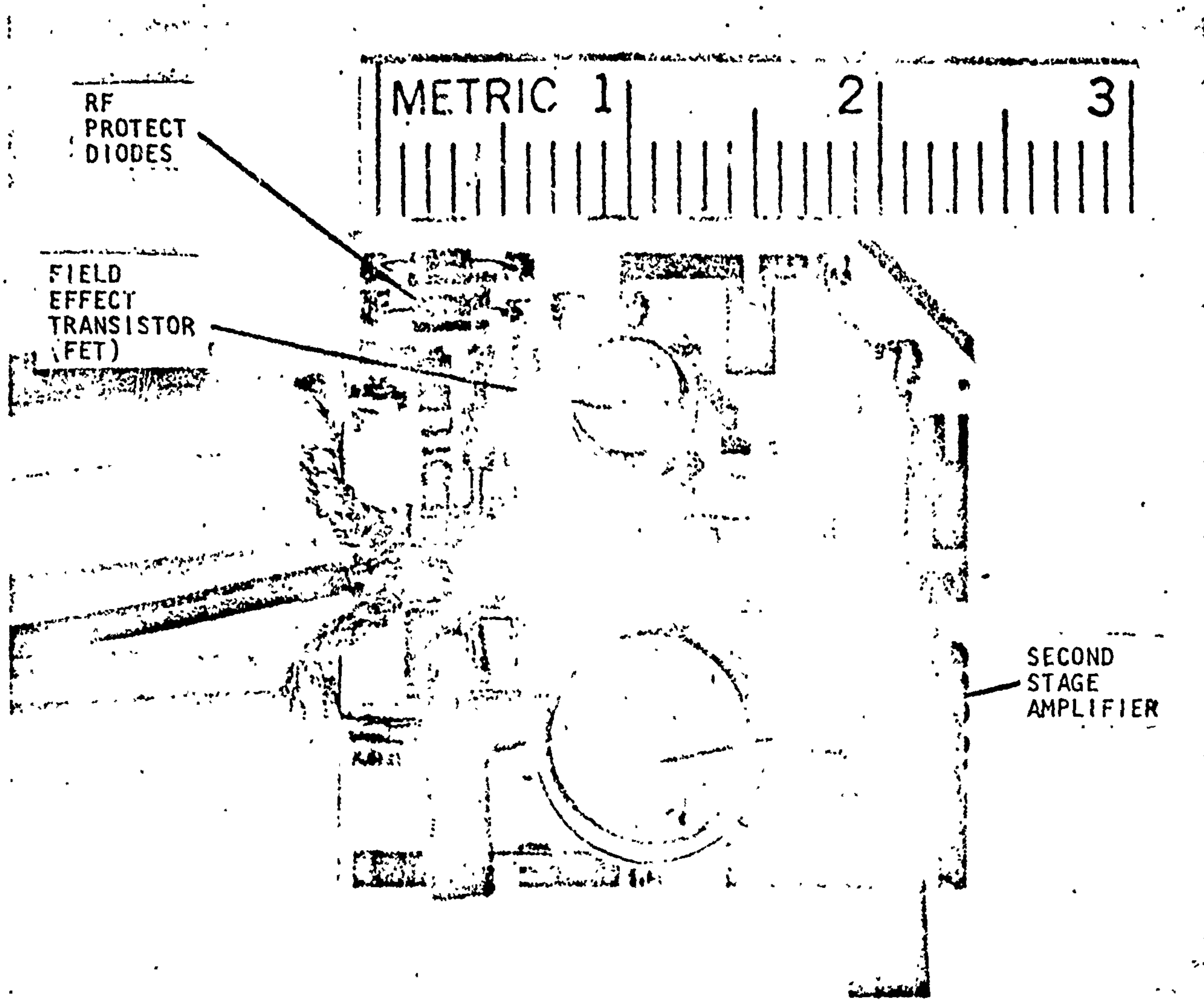
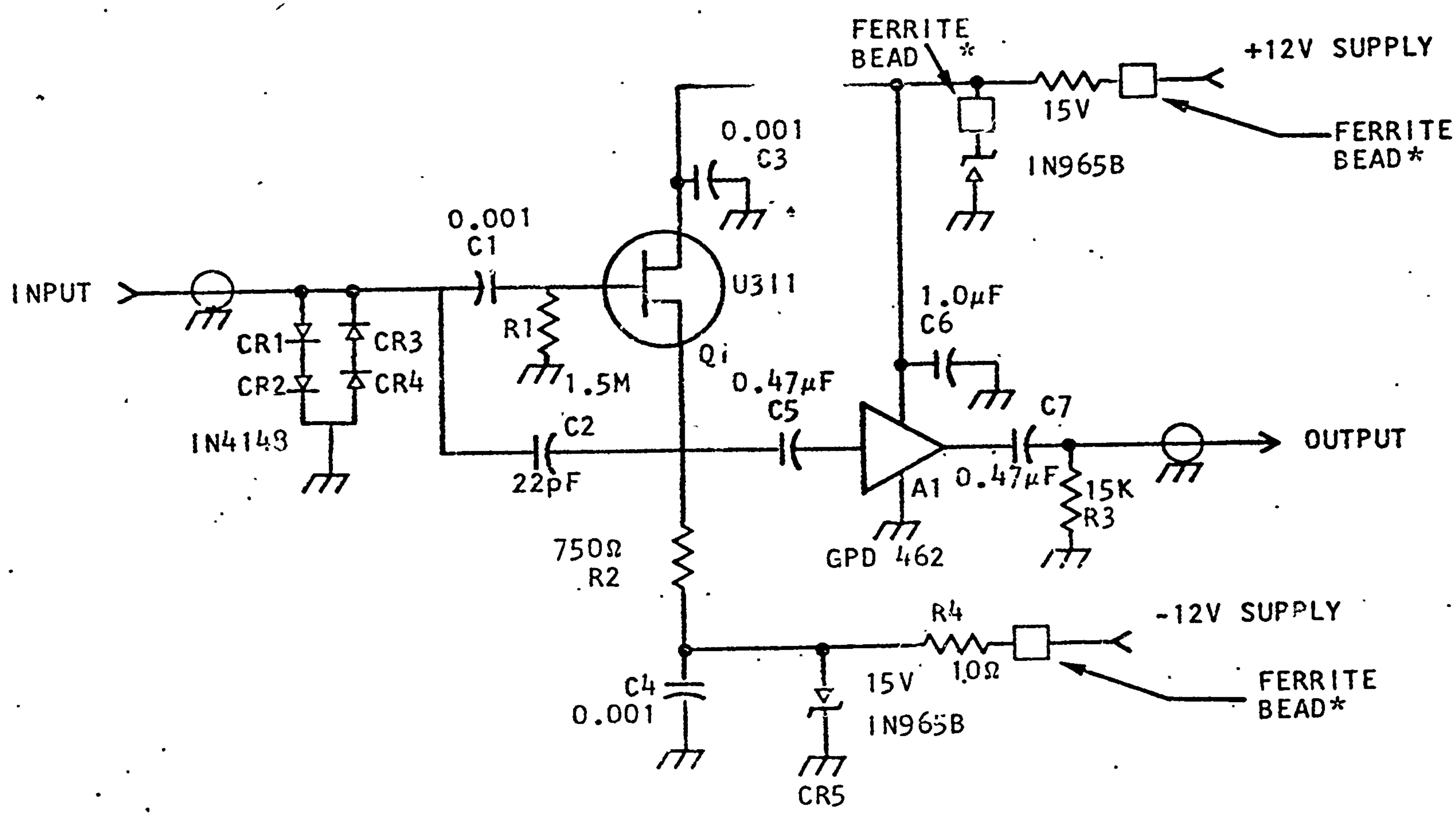


Figure 2-1. Matching Network/Amplifier Module Prior to Encapsulation.



NOTES:
1. THE IN4148 DIODES ARE FOR LARGE SIGNAL PROTECTION.
2. THE IN965B ZENERS ARE FOR POWER SUPPLY TRANSIENT PROTECTION.
3. THE 15K OUTPUT RESISTOR IS FOR TRANSIENT PROTECTION ON LONG CABLE RUNS.

* FERROX CUBE 55 59065/4A

Figure 2-2. VPA Amplifier Schematic.

2.2 Continued.

low until the input impedance of the amplifier approaches that of the second-stage amplifier A1. At high frequencies (above 100 MHz), the first-stage amplifier Q1 adds very little to the performance of the circuit.

Diodes CR1 and CR4 provide burnout protection for the input of the amplifiers. Resistor R3 is provided to suppress transients on the output cables so the voltage limitations of the output capacitor are not exceeded.

2.3 PERFORMANCE.

The amplifier performance specifications, measured in a 50-ohm test system, are given in Table 2-1.

TABLE 2-1. VPA AMPLIFIER PERFORMANCE.

Parameters	Values
Frequency Range	5 kHz to 500 MHz
Gain	11 dB ±1 dB
Noise Figure	3 dB at 150 MHz and 400 MHz
Output Power (1 dB Compression)	6 dBm
Intercept Point (Third Order)	17 dBm
DC Power	45 mA at +12 Vdc 15 mA at -12 Vdc
Physical Size	1x1x0.5 inches

It must be noted that the amplifier, as encapsulated, has a 75-ohm matching cable on the input that is actually part of the antenna. It is required to tune the antenna to 150 MHz and 400 MHz, as well as to transform its impedance to 50 ohms. This will change the apparent performance of the amplifier, both in terms of gain flatness and noise figure. Figure 2-3 and Figure 2-4 show the performance measured directly at the amplifier input and at the input to the 75-ohm cable.

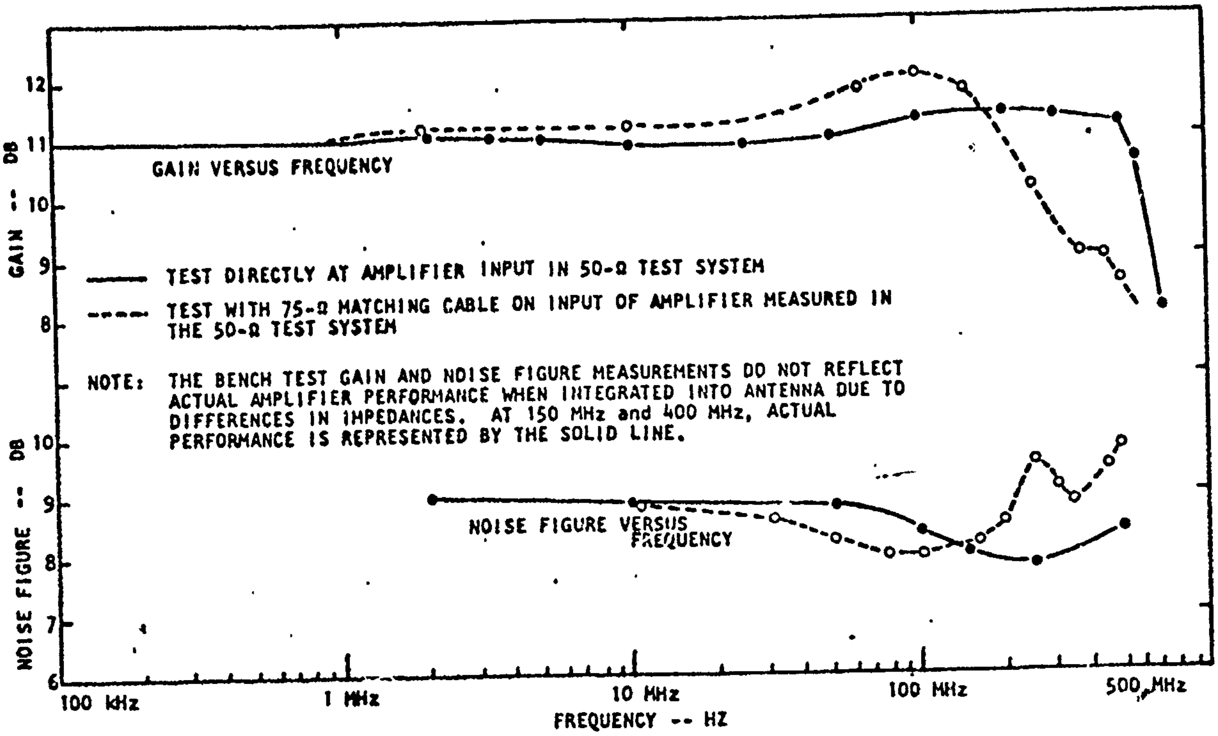


Figure 2-3. VPA Amplifier Performance Versus Frequency.

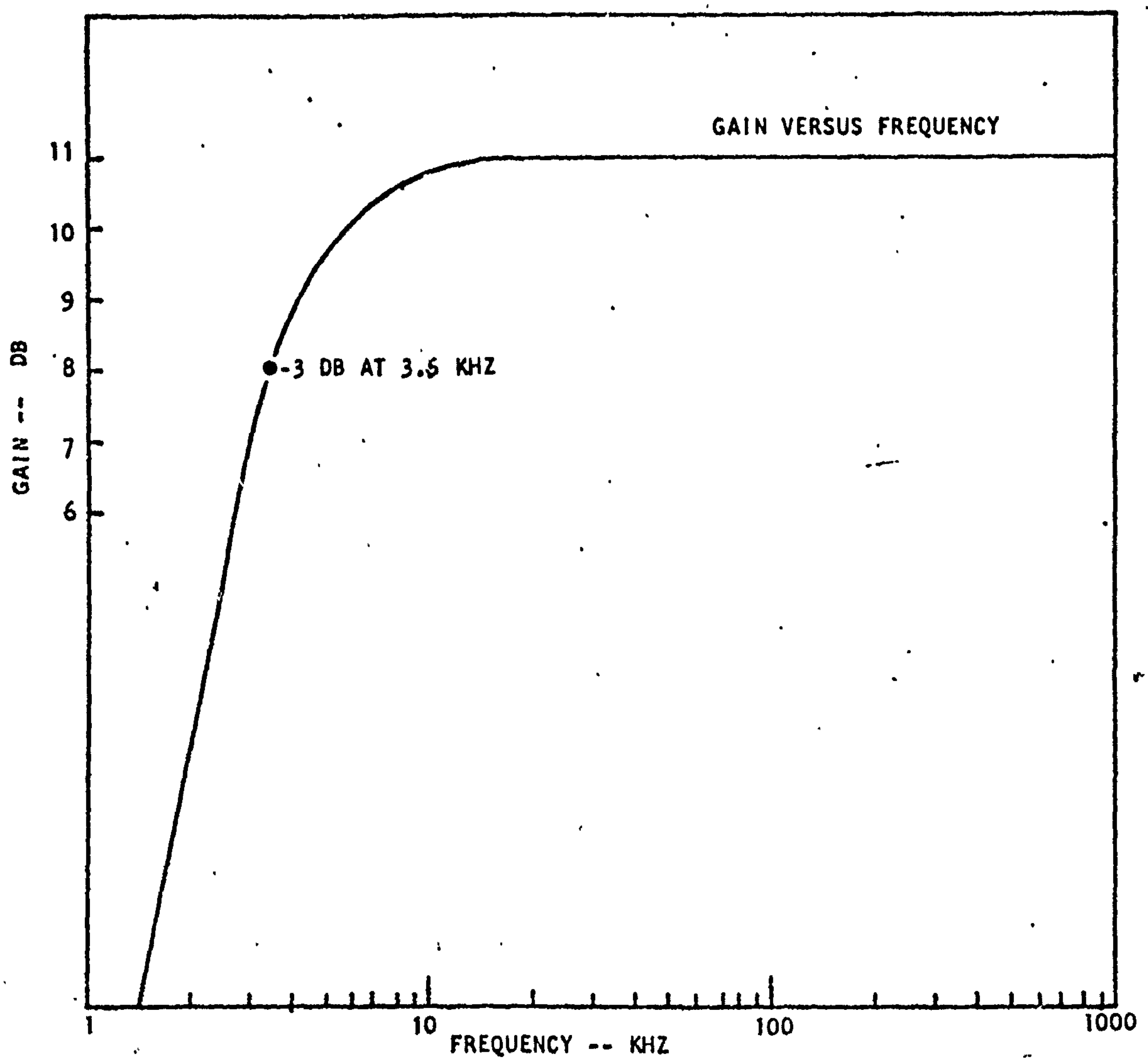


Figure 2-4. Low-Frequency Response of VPA Amplifier in 50-Ohm System.

2.3 Continued.

A plot of the input impedance (Figure 2-5) is also provided. It clearly shows the rapid increase in impedance with decreasing frequency provided by the described active matching technique. The 75-ohm matching cable also effects the input impedance and is depicted on the plot.

2.4 DESIGN CONSIDERATIONS.

The amplifier design is constrained by four primary considerations.

a. The output impedance of the antenna into which the amplifier must work.

b. The amplifier noise figure.

c. The intermodulation requirements.

d. The requirements for very small amplifier size.

The antenna is physically very small and, therefore, has very high input impedance at low frequencies. At high frequencies, the antenna becomes very reactive and unpredictable, except at 150 MHz and 400 MHz, where it has been optimized to be approximately 50 ohms. Ideally, the amplifier input impedance should be the conjugate match of the antenna at all frequencies. However, due to the widely varying antenna impedance, this would be extremely difficult to obtain in practice. Therefore, an amplifier with infinite input impedance that would transform the EMF developed across the antenna to a 50-ohm load would be a good compromise for achieving a broadband integrated antenna.

At this time, the state of the art in semiconductor devices does not permit the design of a low-noise broadband amplifier with an input impedance much greater than 200 ohms at 500 MHz. At 500 MHz, only 1.5 pF of stray capacity is required to account for a shunt impedance of 200 ohms. The actual stray capacity would be several times this value in practice.

It was decided, on the basis of realizable amplifier input impedance, to design an amplifier with very high input impedance at low frequency and approximately a 50-ohm impedance at 150 MHz and up.

2.3 Continued.

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The antenna is physically very small and, therefore, has very high input impedance at low frequencies. At high frequencies, the antenna becomes very reactive and unpredictable, except at 150 MHz and 400 MHz, where it has been optimized to be approximately 50 ohms. Ideally, the amplifier input impedance should be the conjugate match of the antenna at all frequencies. However, due to the widely varying antenna impedance, this would be extremely difficult to obtain in practice. Therefore, an amplifier with infinite input impedance that would transform the EMF developed across the antenna to a 50-ohm load would be a good compromise for achieving a broadband integrated antenna.

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It was decided, on the basis of realizable amplifier input impedance, to design an amplifier with very high input impedance at low frequency and approximately a 50-ohm impedance at 150 MHz and up.

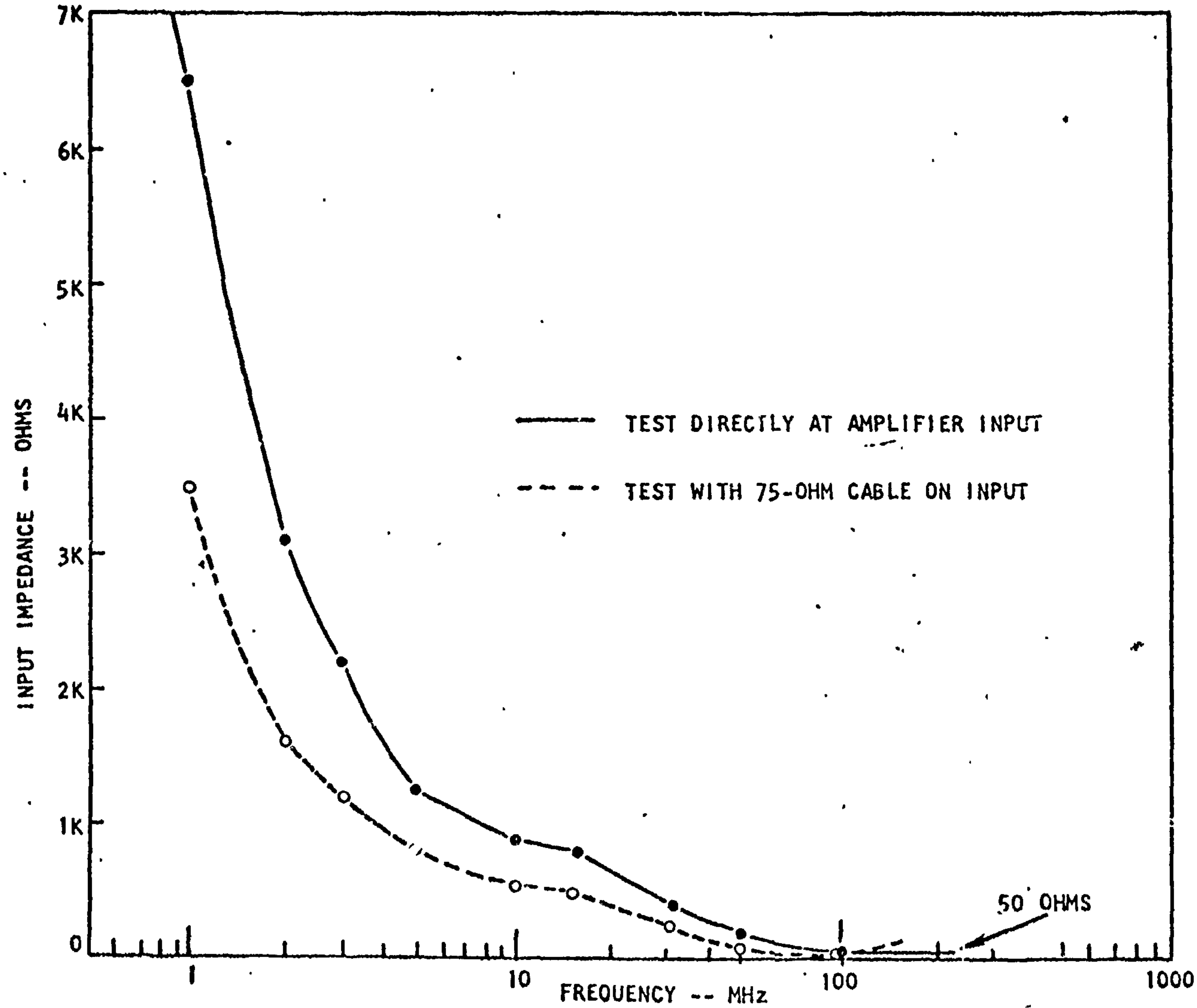

Figure 2-5. Input Impedance [Mag (Z_{in})] Versus Frequency.

2.4 Continued.

To obtain low-noise performance at low frequencies where the source impedance is large, a field-effect transistor (FET) is the obvious choice. The equivalent input noise current in an FET is an order of magnitude lower than a bipolar transistor. Since the signal current supplied by the antenna will be very small at low frequencies due to its high impedance, the signal-to-noise ratio (on a current basis) will be significantly better with a FET. In addition, an FET presents a much greater impedance to the antenna at low frequencies, which results in less antenna loading and increased power gain.

At high frequencies, the bipolar transistor is the obvious choice due to its much greater gain-bandwidth product. The most advanced silicon FET currently available has a gain-bandwidth product of approximately 400 MHz. Such a device can, at best, provide only unit voltage gain up to 400 MHz and can only degrade circuit performance above this frequency.

On the basis of the foregoing discussion, an FET and bipolar combination becomes the most reasonable approach to the problem. Noise figure at high frequency becomes a matter of selecting the proper bipolar amplifier and reducing the noise contribution of the FET to a minimum. The intermodulation requirements become a matter of selecting the appropriate bipolar amplifier and limiting its gain to the minimal value required to overcome cable losses. The size of the amplifier (1 inch by 1 inch by 0.5 inch maximum) requires a simple circuit with an absolute minimum number of components.

The circuit described in paragraphs 2.1 was the outcome of the design effort. The FET provides active impedance matching and unit voltage gain up to approximately 100 MHz, which is the "crossover" frequency. Above 100 MHz, the signal is coupled around the FET by a bypass capacitor directly into the second-stage amplifier. At these frequencies and above, the FET only contributes noise to the circuit performance. Essentially, the increase in noise figure at high frequencies is the compromise for obtaining wideband performance from a short antenna.

Noise figures as low as 4.0 dB could be obtained at the optimized frequencies of 150 MHz and 400 MHz using the appropriate bipolar transistor-type amplifier. However, at frequencies below 50 MHz, the antenna-amplifier combination would begin

2.4 Continued.

to have seriously impared performance due to gross impedance mismatch. The FET increases the noise figure to 8.0 dB at the optimized frequencies, but it extends the integrated antenna performance down to a frequency of 5 kHz.

To ensure that a noise figure of 8 dB is adequate, tangential sensitivity tests were run at 150 MHz and 400 MHz. A NAVSAT receiver with bandwidths of 25 Hz and 40 Hz at 150 MHz and 400 MHz, respectively, and the expected received power from a navigational satellite were used as references to estimate the required tangential sensitivities. Calculations showed that the expected field strength at the antenna would be 1.8 μV/meter, minimum, under actual conditions. Tests were made in which the antenna-amplifier combination was immersed in a known field strength, and tangential sensitivity measurements were taken. In a 25 Hz bandwidth, the tangential sensitivity at 150 MHz was 1.08 μV/meter, and in a 40 Hz bandwidth, the tangential sensitivity at 400 MHz was 0.91 μV/meter. These sensitivities are approximately equivalent to a 12 dB signal-to-noise ratio at 150 MHz and a 14 dB signal-to-noise ratio at 400 MHz. Since these S/N ratios are minimum expected values, an amplifier noise figure of 8.0 dB was considered adequate.

The circuit was constructed using thick film and ceramic substrate techniques. This method is particularly advantageous in the case of the VPA amplifier due to the size and heat dissipation requirements. The high heat conductivity of the ceramic substrate effectively heat-sinks the 700 mW dissipation of the circuitry. The prototype amplifier was encapsulated in a low-loss dielectric substance, although a metal can was considered and was then discarded due to schedule considerations

2.5 ALTERNATE DESIGNS CONSIDERED.

Many alternate designs were considered, but they all basically used the FET-bipolar combination for the reasons discussed in the previous paragraphs. These designs in all cases, attempted to increase the bandwidth and reduce the noise figure of the FET amplifier stage. Both the bandwidth and noise figure were limited by losses introduced by the FET as the frequency increased. Above 100 MHz, the FET adds noise directly to the RF input without adding voltage gain. The ideal situation would be to have FET that would provide voltage gain over the required bandwidth, but this was impossible due to gain bandwidth limitations in the device itself. A new gallium-arsenide FET was also

2.6 Continued.

considered that has a very high gain-bandwidth product of 30 GHz, but at its present stage of development, is more of a laboratory curiosity and was discarded due to its unavailability, unreliability, and unknown performance characteristics.

The only other approach that seemed promising was based on the theory that having a high input impedance (approximately 200 ohms or greater) bipolar transistor amplifier as the second stage would greatly reduce loading effects on the FET. This would reduce the noise figure by reducing losses at the FET-bipolar interface. Two techniques were tried, based on this theory. The first used an emitter follower second stage, but proved unstable and tended to oscillate due to stray reactances. The second technique used a common emitter stage with emitter degeneration to increase input impedance and this, in fact, worked; however, due to the high collector impedance required, this technique severly reduced the bandwidth of the bipolar transistor to approximately 250 MHz. It was at this point that the final circuit configuration was decided upon.

Section 3

VOLTAGE PROBE ANTENNA, ELEMENT DESIGN

3.1 PHYSICAL CONSIDERATIONS.

Several basic problems were involved in the design of the antenna element, the first of which was its location in the existing structure. Since there is very little spare space in the existing antenna structure, it was decided that the antenna element would be a thin metallic strip winding at a 45-degree angle alongside the existing biconical antennas (see Figure 3-1). Running the element at a 45-degree angle, parallel to the polarizing grids on the biconical antennas, creates a minimum of interface with the performance of these existing antennas. This technique was used previously on an experimental model of this antenna with great success.

3.2 IMPEDANCE MATCHING.

The next problem was to design an antenna configuration that would have an impedance near 50 ohms at 150 MHz and 400 MHz. Since the basic antenna element was predetermined by the physical constraints of the assembly, this left both ends of the element available for impedance matching. (A balanced dipole-type configuration using two elements was examined, but the omnidirectionality of the azimuth patterns was quite bad at some frequencies.) At the bottom end of the antenna, a 6-inch length of coax was chosen to feed the antenna element. Because the feed is unbalanced, the outer shield of the coax is connected to the skirt of the high band biconical for grounding purposes (see Figure 3-1). This keeps the currents from flowing down the coax on the outer conductor, which would make the antenna very inefficient and hard to impedance-match. It was determined that a higher impedance cable such as the RG 187/U (75 ohms) provides a better impedance transformation for the antenna than does the standard 50-ohm cable.

At the top end of the antenna element, several impedance matching techniques were tried. The most successful of these employed a four-arm spiral etched on a thin epoxy fiberglass printed wiring board (see Figure 3-1). The end of the antenna element is soldered to the end of arm 1 of the spiral (the arms are numbered in a clockwise direction). Arm 1 is connected to arm 3 at the center (normal feed point) of the spiral.

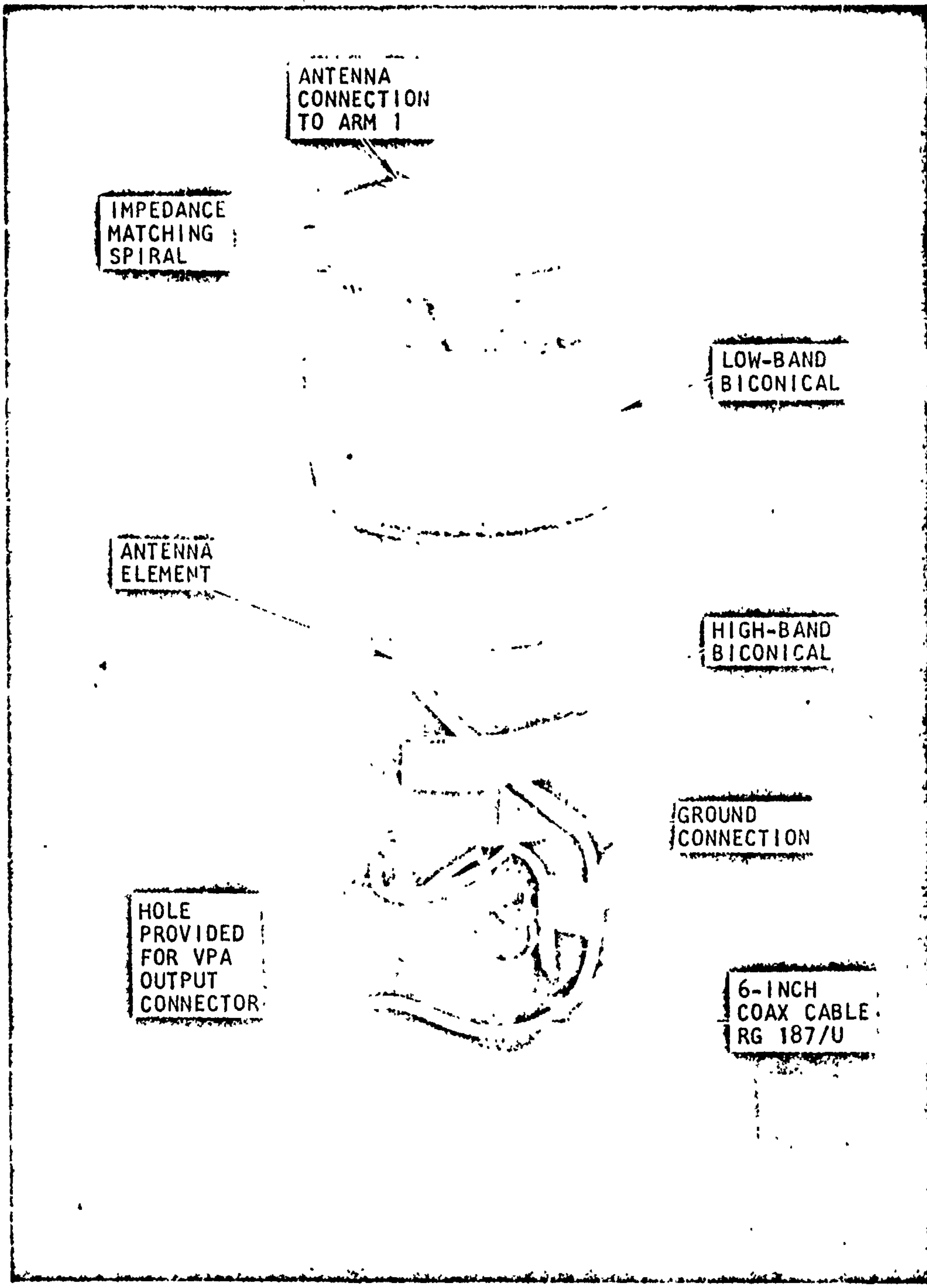

Figure 3-1. VPA in Impedance Matching Stage.

3.2 Continued.

Arm 2 is connected to arm 4 at the center, but not to arms 1-3. The interaction of arms 2-4 on the antenna impedance is similar to that of a parasitic element of the antenna. The impedance of the antenna is tuned by trimming (cutting back) the ends of arms 2, 3, and 4. The proper combination of trimming will cause the impedance at 150 MHz to be approximately 50 ohms and at 400 MHz to be between 25 and 30 ohms with very little reactive component.

The impedance was measured using a swept network analyzer setup. Figure 3-2 shows a swept impedance plot of the prototype antenna from 150 MHz to 400 MHz. This data was measured with the radome housing in place over the antenna (which is very important for accuracy). The behavior of the impedance curves between 150 MHz and 400 MHz (and also beyond both ends of this frequency range) should be noted because this is the impedance that the amplifier circuit sees. This impedance is referenced at the equipment or amplifier end of the 6-inch coax (RG 187/U), since it is part of the antenna.

3.3 ANTENNA-AMPLIFIER INTEGRATION.

After the antenna was installed and tuned, and after the amplifier was built and bench tested, the amplifier was installed in place (see Figure 3-3) and connected to the antenna, output connector, and dc power plug. The VPA then underwent some preliminary pattern/gain tests before the assembly was potted (see Figure 3-4) and installed into the radome housing for final testing. It was at this point and during final testing that a problem was discovered that is inherent to the basic antenna structure. This problem is discussed later in this report in Subsection 6.2.

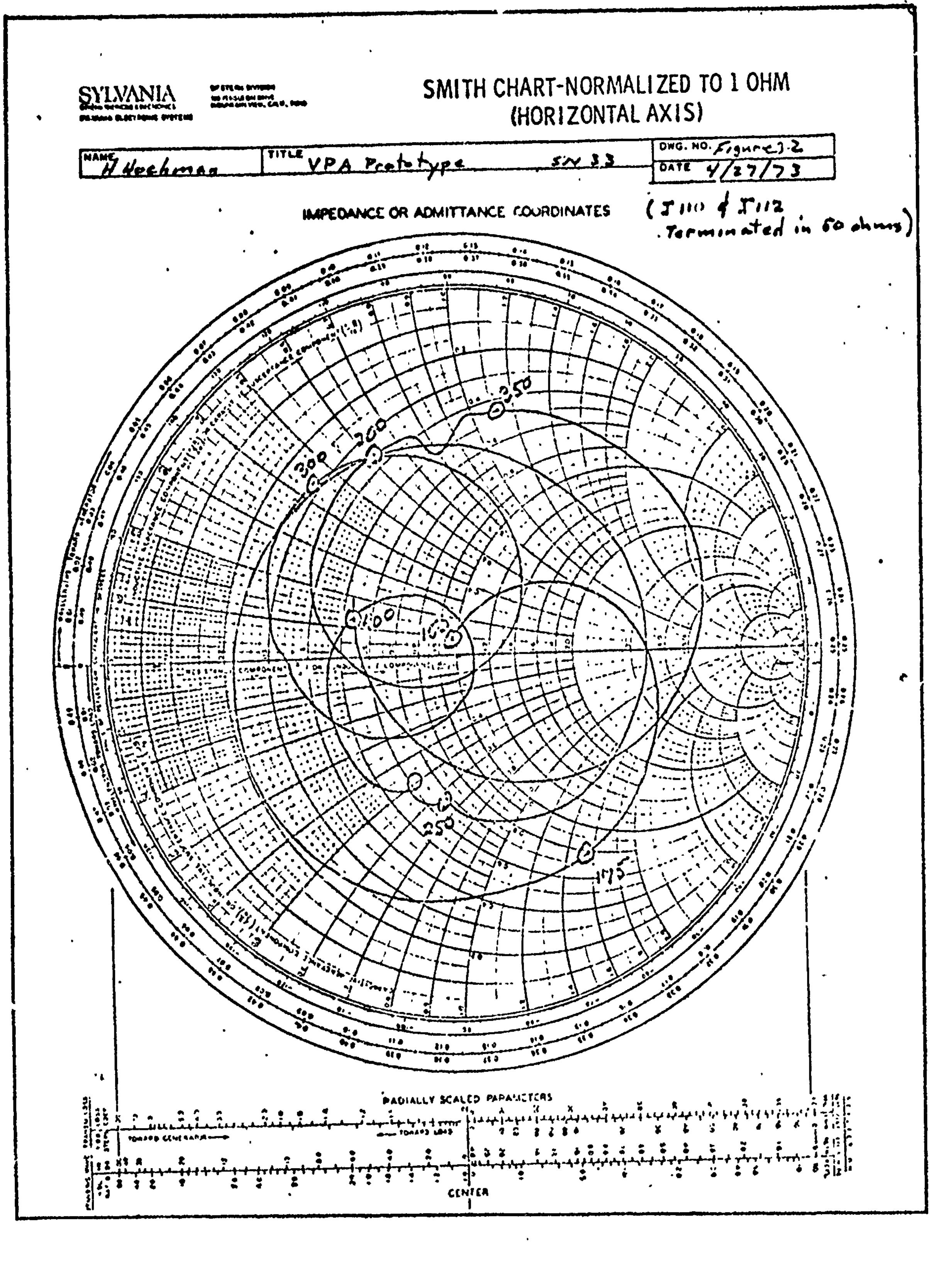

Figure 3-2. Swept Impedance Plot of Prototype VPA

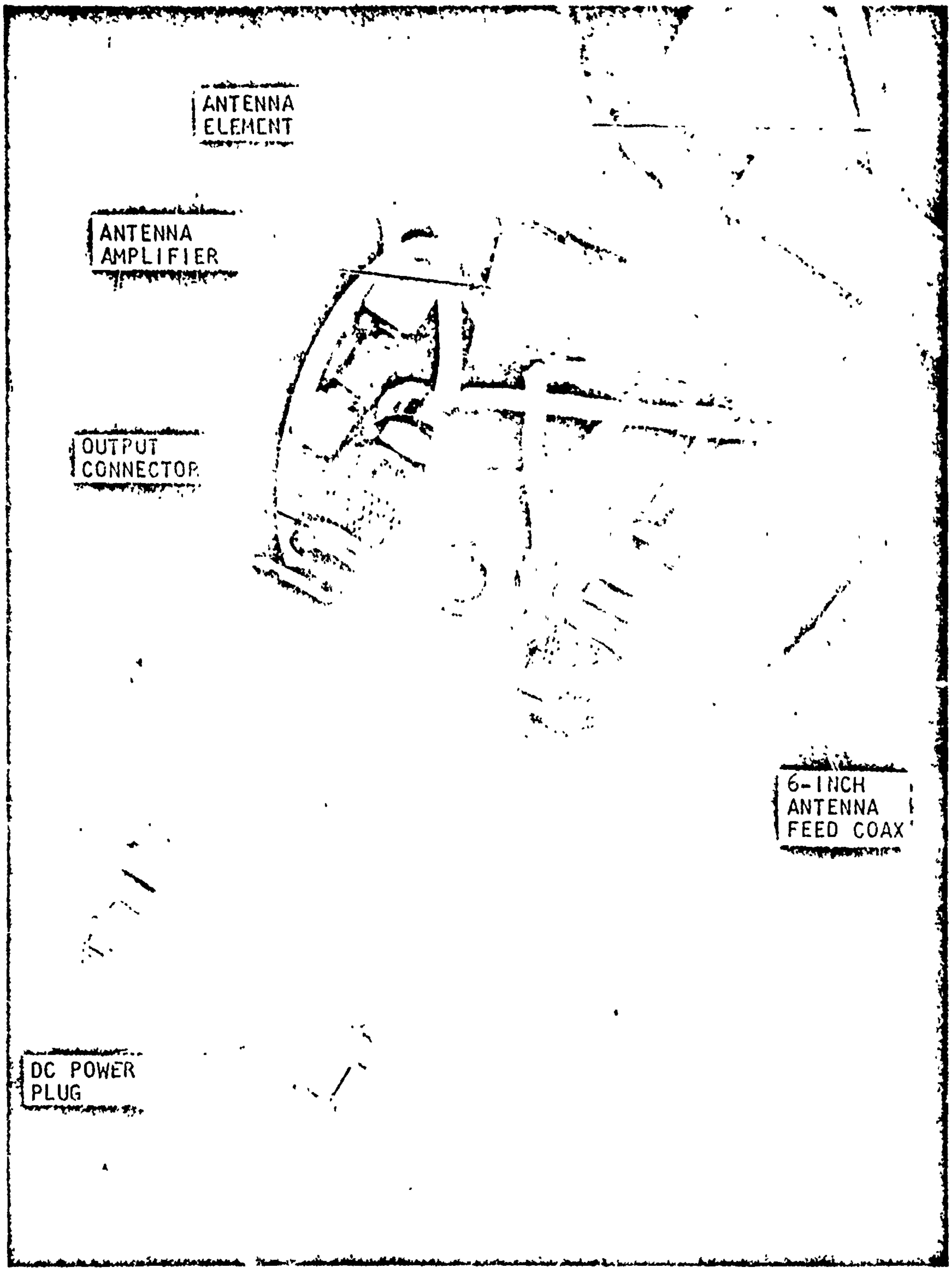

Figure 3-3. Amplifier Installation.

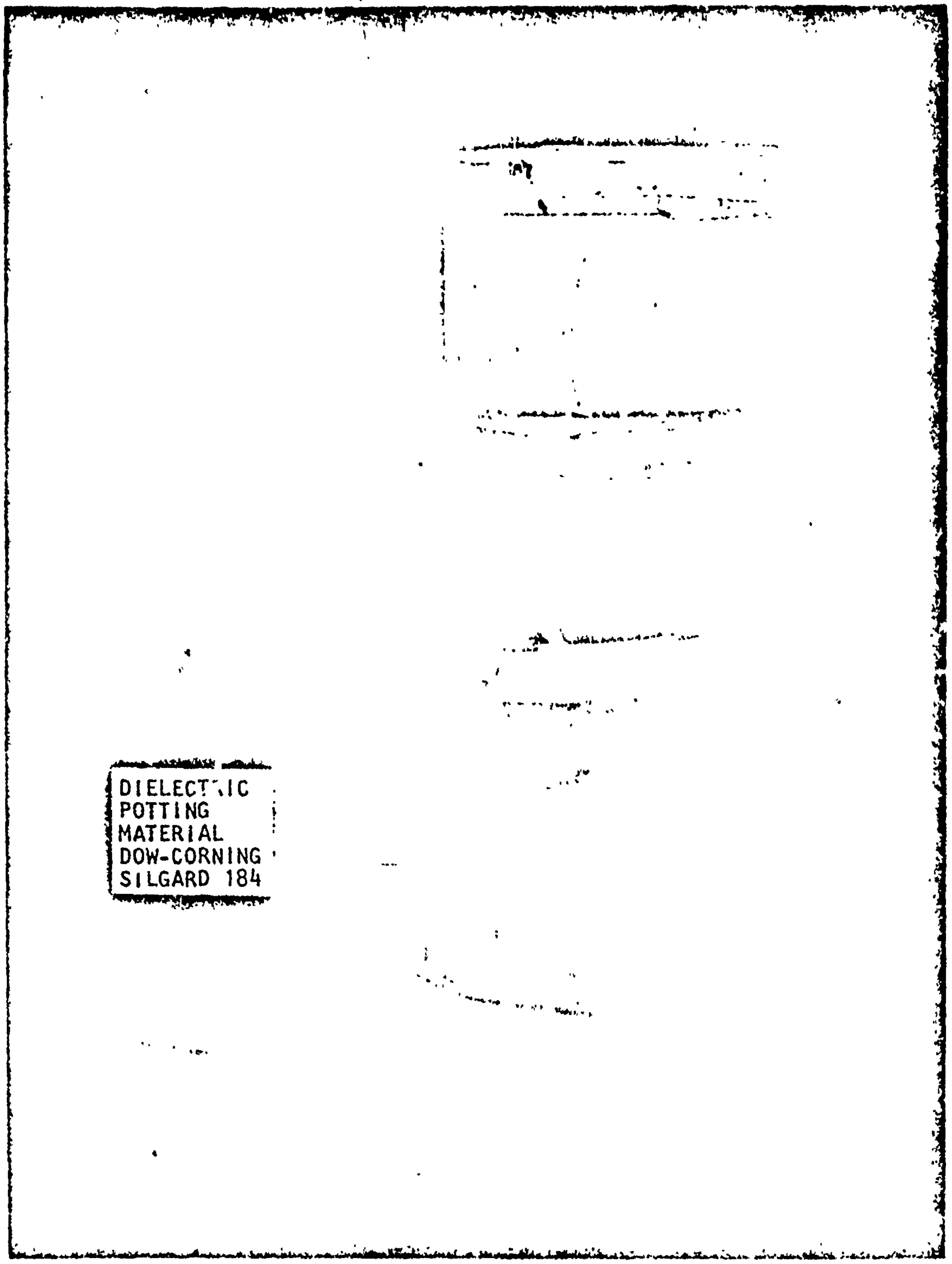

Figure 3-4. Antenna Assembly After Potting.

Section 4

VOLTAGE PROBE ANTENNA, TESTS

4.1 EARTH-BOUND ANTENNA RANGE FACILITY (EBARF) TESTS.

The radiation pattern/gain tests were performed in the field at EBARF, the Earth-Bound Antenna Range Facility. The basic test setup is shown in Figures 4-1, 4-2, and 4-3. The VPA unit is mounted on top of a simulated mast sleeve antenna that is insulated from a metal stand that, in turn, is grounded in the salt water. The elevation patterns of the VPA and the reference dipole are taken by raising and lowering the A-frame with the transmitting antenna. The shape of the elevation patterns and the peak gain of the VPA (major lobes and nulls) at any specific frequency is highly dependent upon the height of the antenna above the surface of the water. (It was planned to take patterns at other heights, but time did not allow this.) The height of the vertical reference dipole above the water was always kept at approximately one-quarter wavelength. Therefore, for gain calculation purposes, the peak gain of the reference dipole at any frequency was assumed to be +4.5 dBi. Based on this assumption, a graph of the measured VPA peak gain was plotted in Figure 4-4.

Conical-cut patterns were recorded by placing the antenna stand on a turntable, elevating the A-frame to a specific angle, and then rotating the antenna. (See Figure 4-3.) A set of measured elevation and conical-cut patterns is given in Appendix A.

The tangential sensitivity of the VPA was measured in a screen room setup. An electromagnetic field was created using a transmission line configuration, and the field strength was measured using calibrated EMI antennas. The VPA was then immersed in this field, and the tangential sensitivity was measured. Table 4-1 shows the calculation of the tangential sensitivity, using the measured data. Figure 4-5 is a plot of the field strength (in μV/meter) at the VPA for a receiver system tangential sensitivity* where the receiver does not degrade the system noise figure. The tangential sensitivity is given for a system bandwidth of 1 kHz. (See Appendix B for a more detailed analysis of the tangential sensitivity calculations.)

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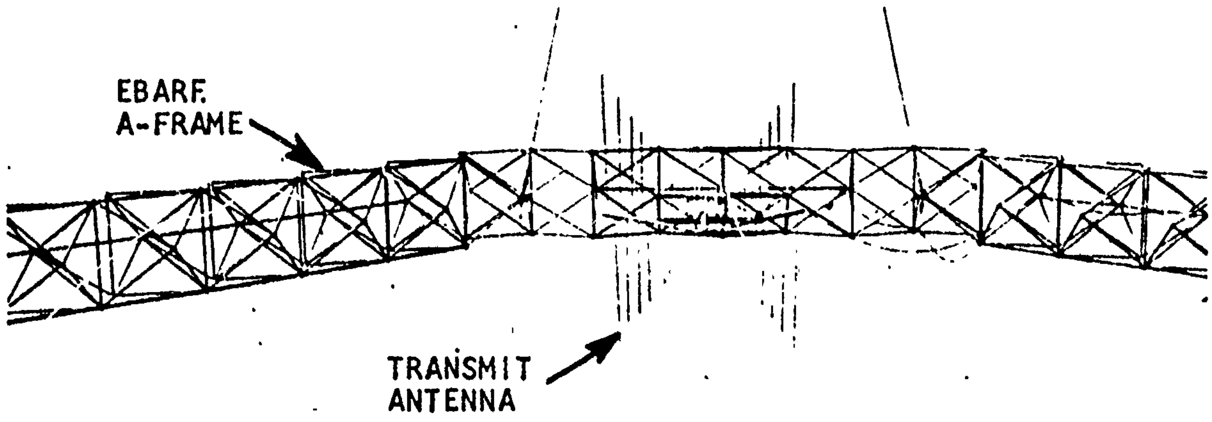
* Tangential sensitivity is equivalent to a signal-to-noise ratio of 8 dB.



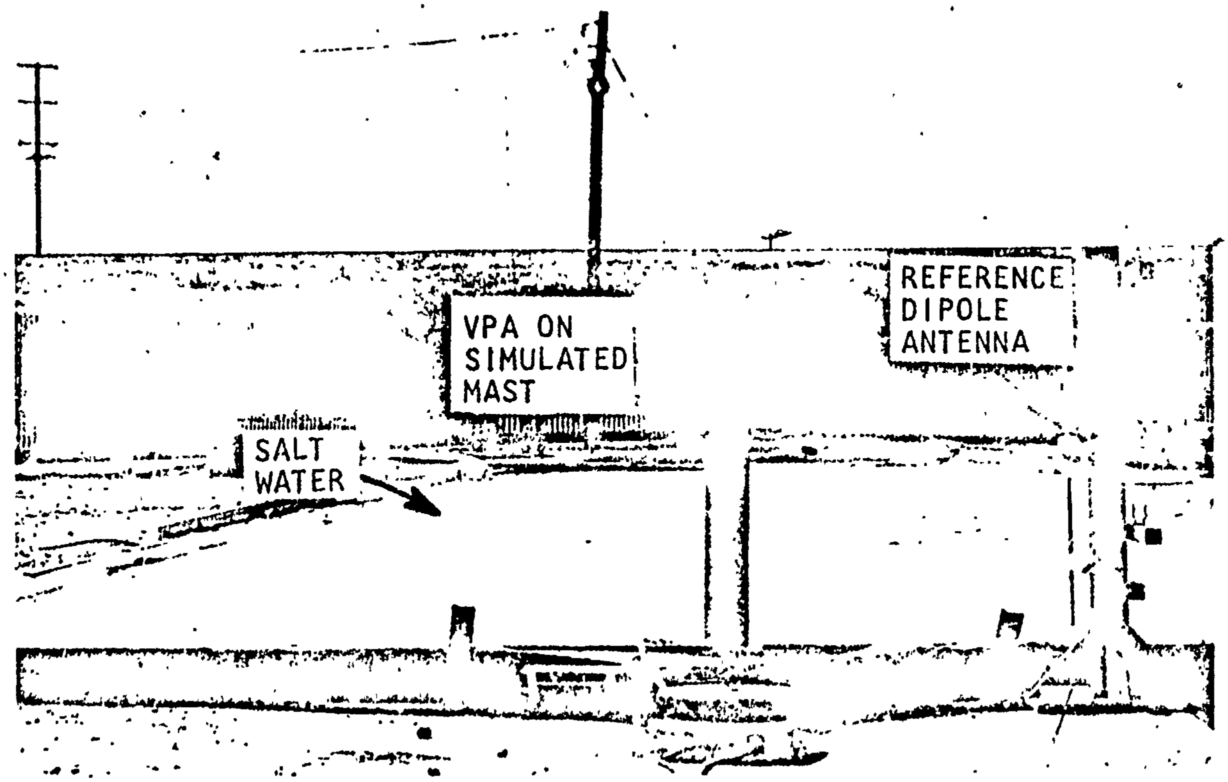


Figure 4-1. EBARF Test Setup.

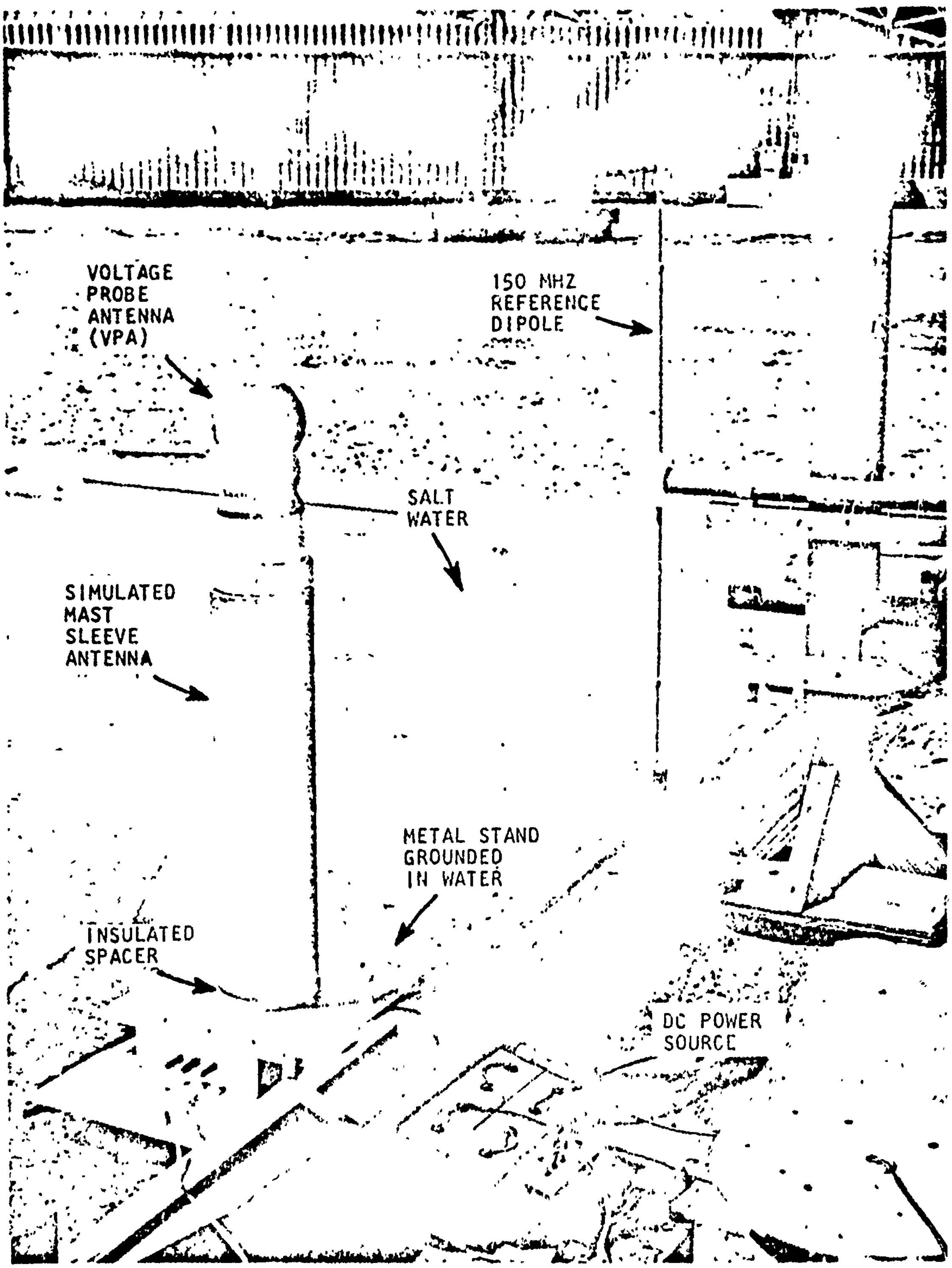


Figure 4-2. Antenna Setup for Elevation Patterns/Gains.

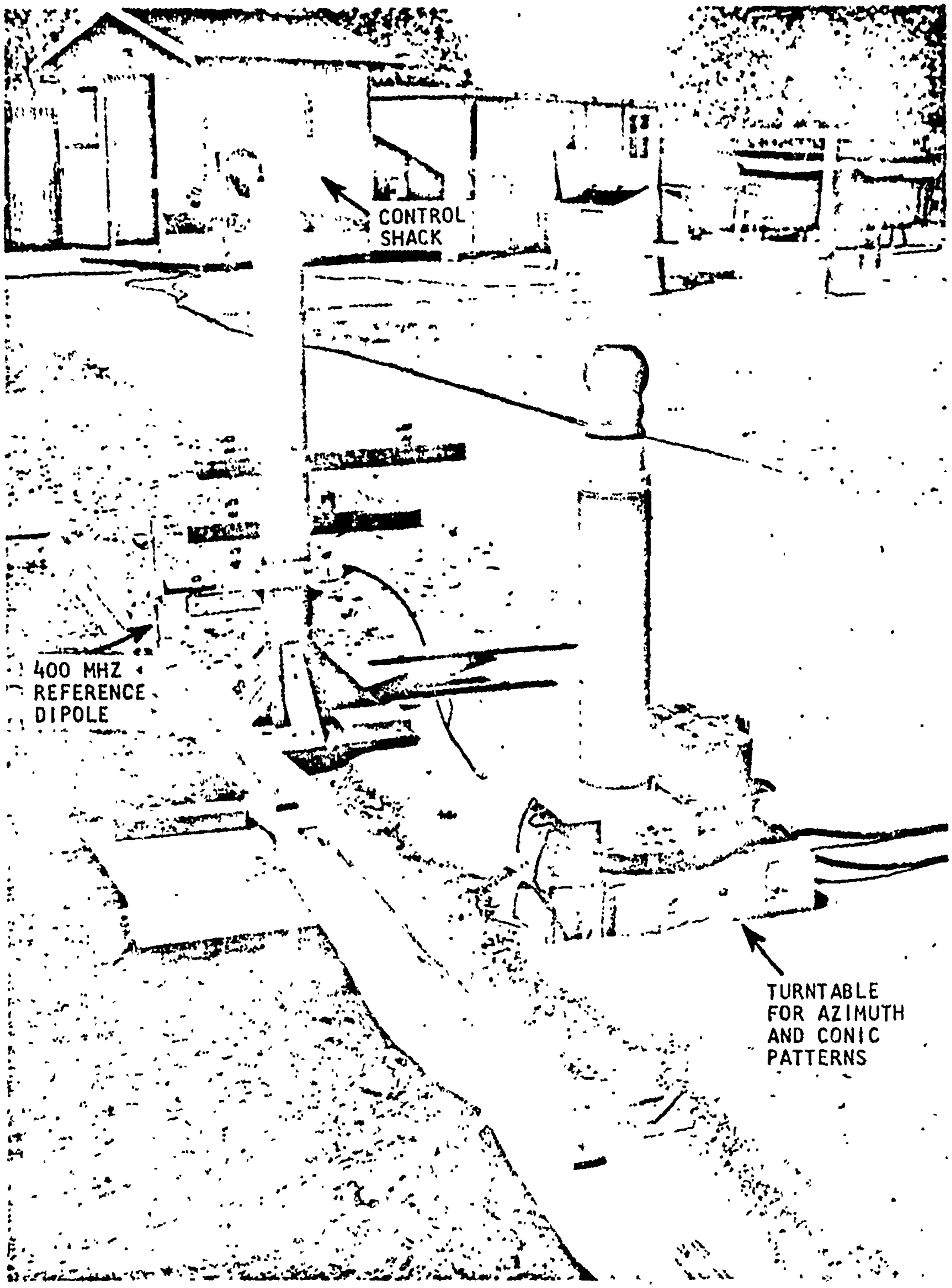


Figure 4-3. Antenna Setup for Azimuth/Conic Patterns.

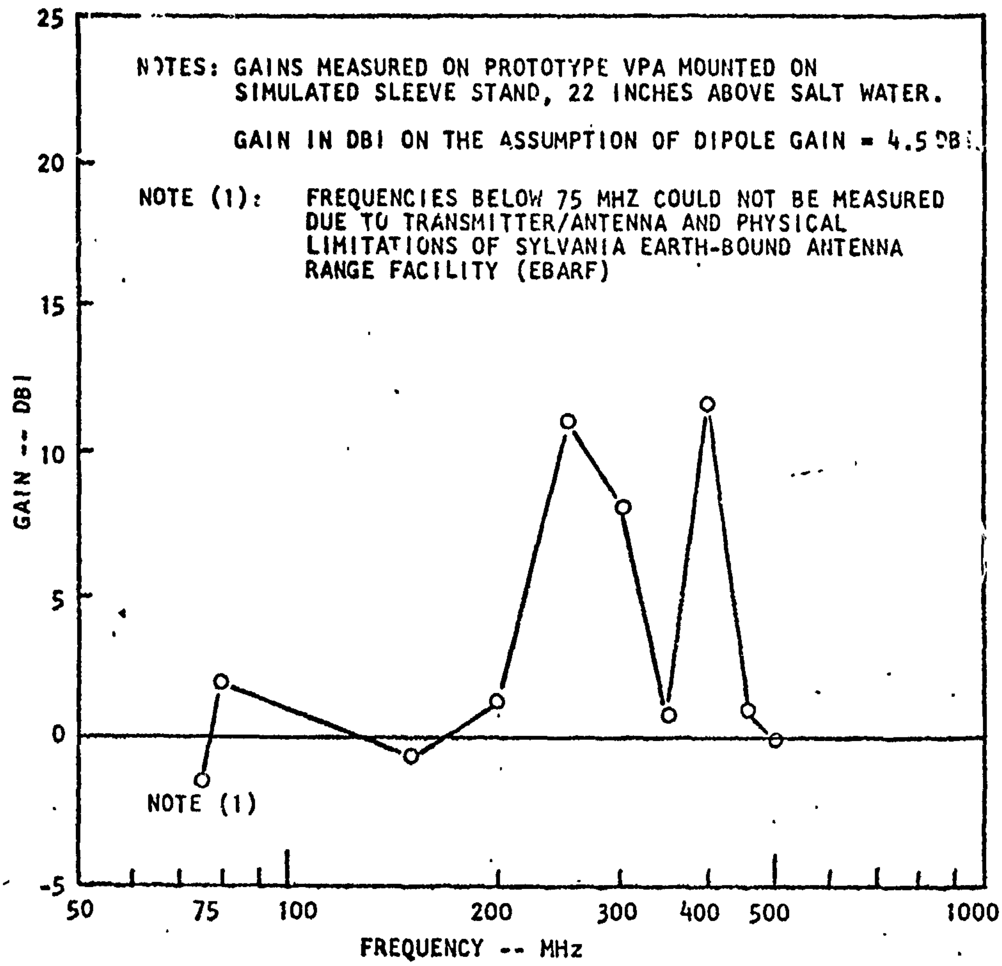


Figure 4-4. Typical Gain Curve for VPA.

TABLE 4-1. TANGENTIAL SENSITIVITY CALCULATIONS.

Frequency (MHZ)	Bandwidth (kHz)	Receiver (NF - dB)	VPA (NF - dB)	dB - μV/meter			Corrected* System TG (μV/meter)
				Measured System TG	System TG in 1-kHz BW	Corrected* System TG	
500	500	14	8.9	48	21	19.9	9.9
400	500	12	8.1	39.5	12.5	11.8	3.9**
300	500	12	7.8	29	2	1.2	1.15
200	500	13	7.8	33	6	5.1	1.8
150	500	14	8.0	43	16	15.1	5.7***
75	500	14	8.8	45	18	16.9	7.0
30	500	15	8.9	50	23	21.9	12.5
10	50	10	8.9	37	20	19.6	9.6
1	5	7	9.0	32	25	24.9	17.6
0.5	5	17	9.0	31	24	22.3	13
0.25	4	17	9.0	34	28	26.3	20.7
0.1	4	21	9.0	34	28	25.0	17.8
0.05	4	21	9.0	40	34	31.0	35

* The two columns of corrected tangential sensitivities are derived by assuming a constant receiver noise figure of 8 dB for purposes of obtaining comparable results. A VPA amplifier gain of 11 dB is used in the calculation where

$$TG_{corrected} = TG + NF_A - NF_T,$$
$$NF_A = \text{VPA noise figure},$$
$$NF_T = \text{system noise figure}.$$

** This is 0.78 in 40-Hz bandwidth.

*** This is 0.9 in 25-Hz bandwidth.

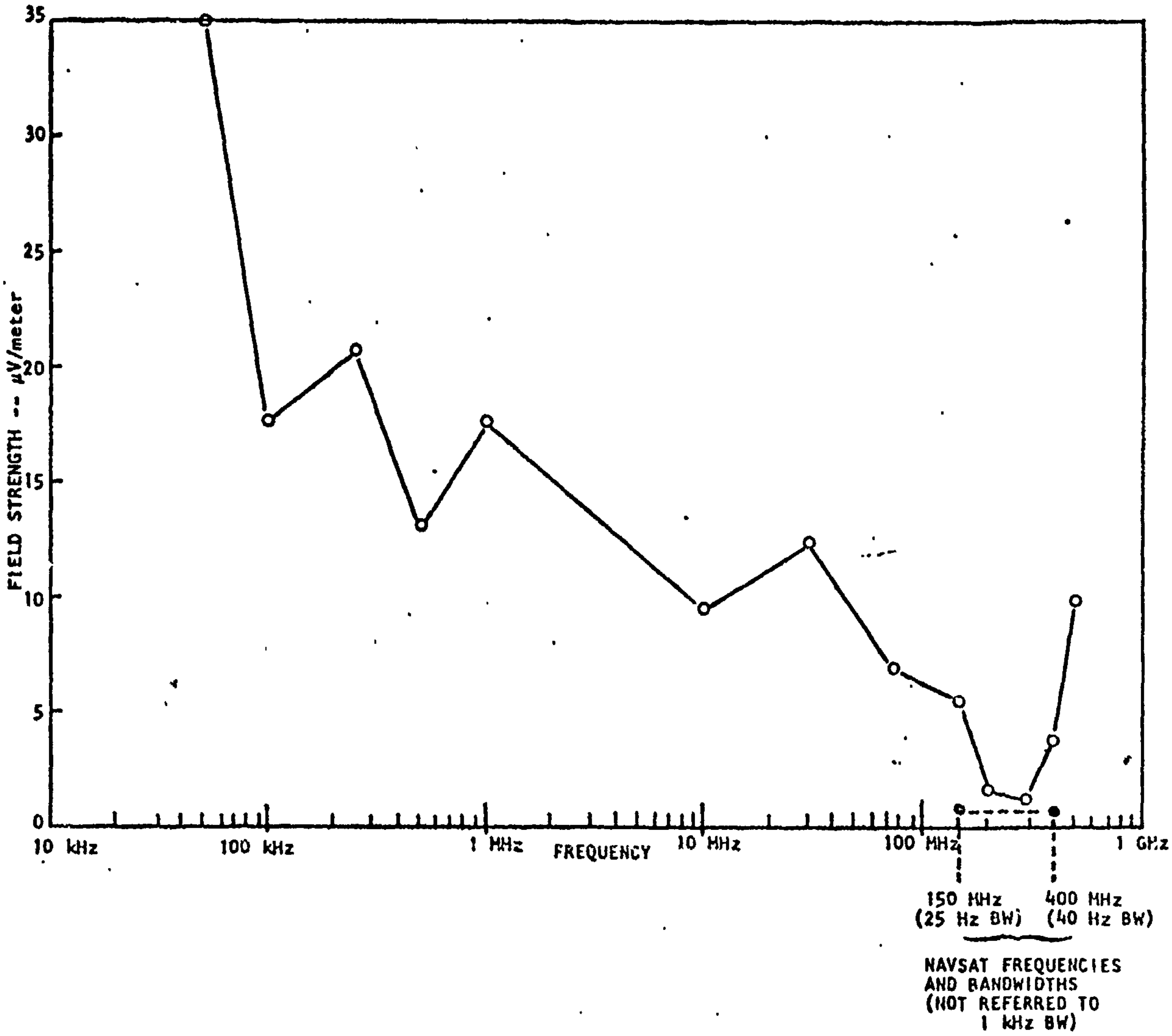


Figure 4-5. VPA Tangential Sensitivity Field Strength (in μV/meter) in a 1-kHz Bandwidth Versus Frequency.

4.2 MAGNAVOX NAVSAT COMPARISON TESTS.

Comparative tests were conducted at Magnavox Research Laboratories in Torrance, California. The VPA was compared alongside a standard test setup at the Magnavox facilities. Tests were conducted with a breadboard VPA unit and a finished unit against actual NAVSAT "passes".

The test setup is shown in Figure 4-6. The Magnavox setup in both tests used a double whip cut for 150 MHz and 400 MHz. The antenna was fed directly to the NAVSAT receiver preamplifier package located on the roof with the antenna. This, in turn, was fed through 30 feet of 50-ohm cable to a NAVSAT receiver, computer, and teletype (TTY) unit. For the first tests, the VPA (a breadboard unit) was situated 56 inches above the roof. [redacted] the NAVSAT preamplifier was located at the end of the 50-ohm cable run (60 feet of cable was required for the run from the VPA to the NAVSAT preamplifier due to physical constraint). The NAVSAT preamplifier fed directly to a second receiver and, in turn, to a computer and TTY.

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The two separate systems were compared simultaneously against 46 separate NAVSAT "passes". Figure 4-7 shows the results of the tests. Out of a possible 40 doppler counts per pass, the specially cut double-whip antenna averaged 80 percent received counts at 400 MHz and 83 percent of the counts at 150 MHz over 46 passes. The VPA averaged 61 percent at 400 MHz and 47 percent at 150 MHz over the same 46 passes. The 80 percent figures for the Magnavox antenna are the expected percentages normally incurred with their testing.

A typical NAVSAT data output is shown in Figure 4-8 for a single satellite pass. The first column is a running total of the possible counts for a given pass. Note that the total possible counts is only 36 out of 40. This is due to signal strength and the azimuthal track across the horizon of the particular satellite sampled. The figures in Figure 4-7 are, however, based on the assumption that 40 counts are available for each pass. The number under the column marked "4ØØ CH" and "15Ø CH" represents that a count was taken in the 400 MHz channel and the 150 MHz channel, respectively. At the bottom of the figure, the computer calculations result in latitude and longitude outputs, along with other various data.

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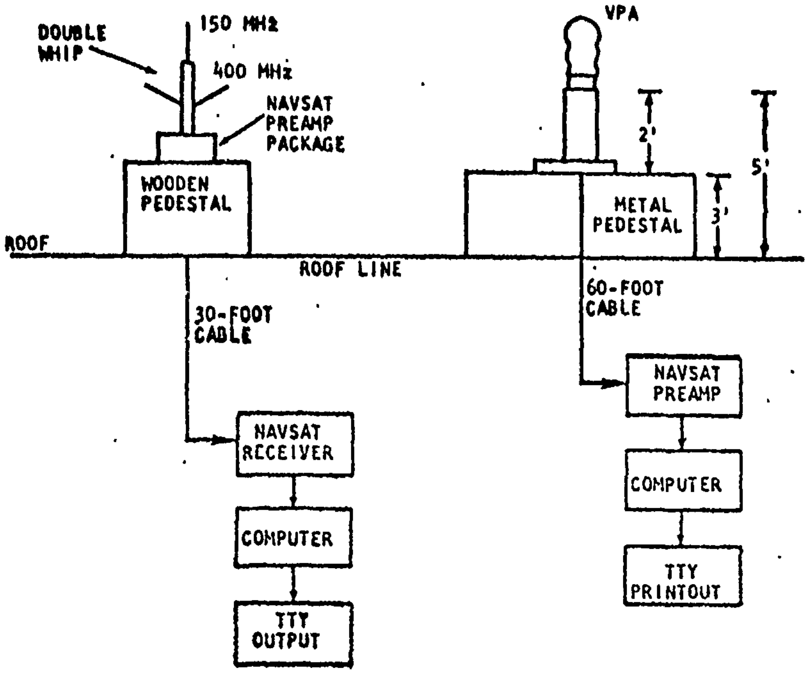
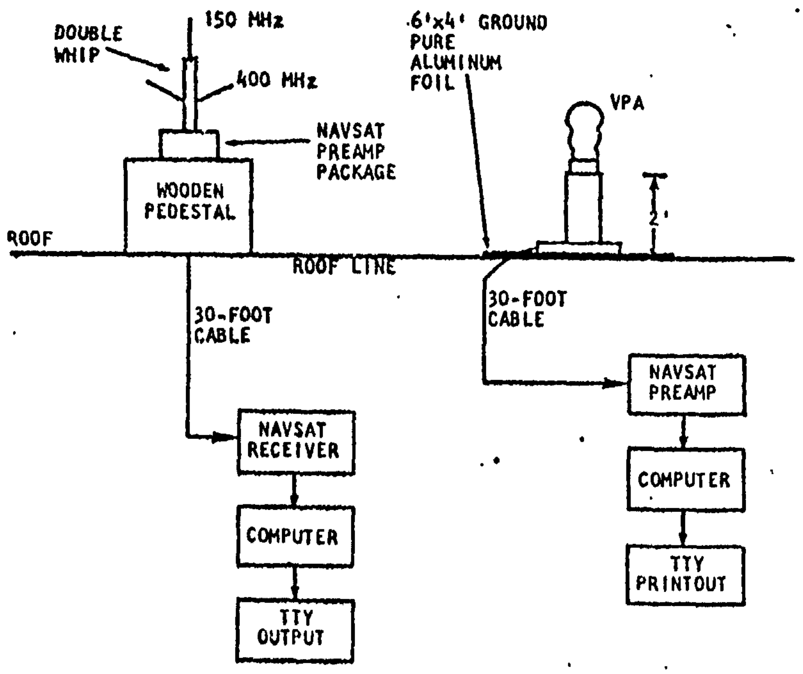
For the second test (Figure 4-6), a completed VPA was used. The VPA test setup was modified, as shown, [redacted] During this test, equipment failure in the standard path resulted in a loss of standard



a. First Tests.



b. Second Tests.

Figure 4-6. Test Setups Used for First and Second Tests.

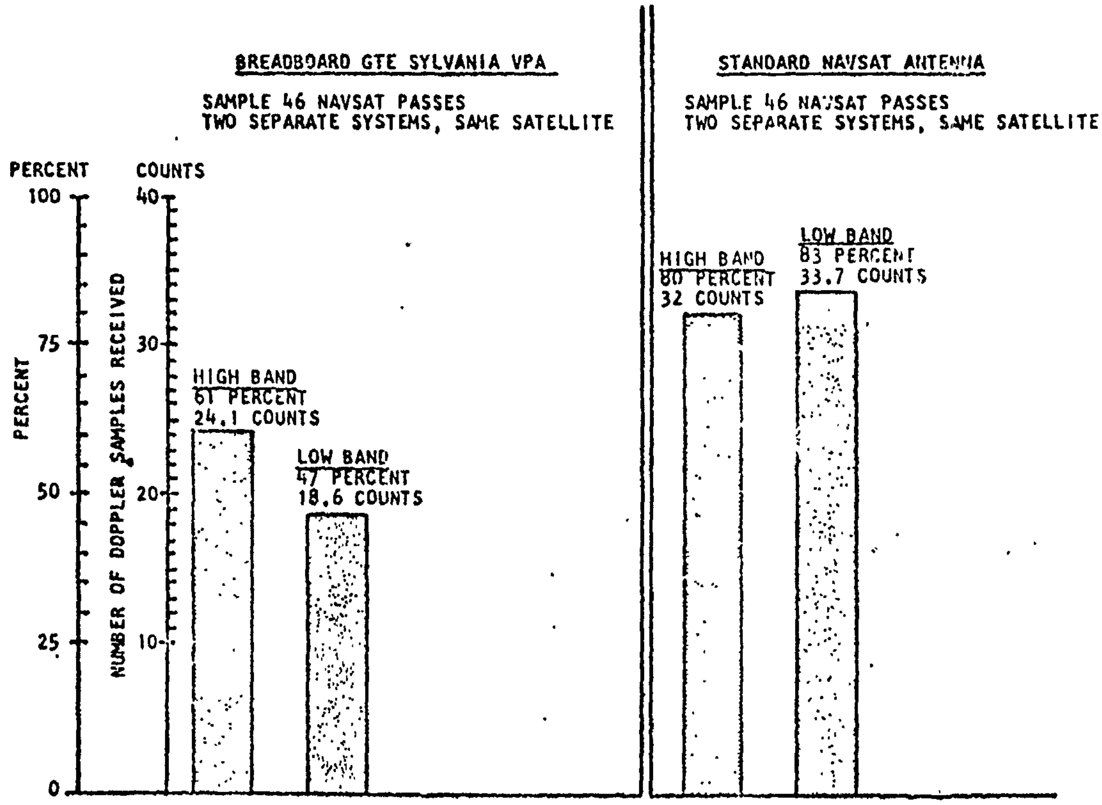


Figure 4-7. VPA Comparative Data for First Tests.

```
 NO.  400-CH     150-CH     COUNT

 01   570074     570088     -12
 02   575152     575166     -14
 03   581352     581365     -14
 04   588909     588926     -15
 05   728902     728916     -14
 06   612133     612143     -10
 07   626333                 **
 08   643277                 **
 09   663116                 **
 10   837174                 **
 11   716051                 **
 12   742190                 **
 13   760089                 **
 14   792537                 **
 15   993442                 **
 16   837748                 **
 17   853562                 **
 18   866725     866720      6
 19   877573     877566      7
 20   1079165    1079159     7
 21   895137     895135      3
 22   900844     900841      2
 23   905521     905521
 24   909363     909362      2
 25   1110191    1110192    -1
 26   915608     915612     -4
 27   917654     917657     -3
 28   919322     919319      3
 29   920694     920694
 30              1121232     **
 31              922819      **
 32              923456      **
 33              923969      **
 34                          **
 35                          **
 36                          **

20382789
20212674
20052492
00092244
00201954
00281614
00331266
00350914
00330577
00270284
40189037
50070144
00000000


06382809
83669615
81912583
30019911
80007494
80746226
82780371
90000028
80000309
80247017
81000000

02 1134

01     32038.893      30.896270      0.0000083     -0.0000772
02     32038.893     -0.0032315     -0.0000083     -6.0000001.
SAT FIX MAPS-B-70356

DAY     TIME         LATITUDE       LONGITUDE        ANT      HDG      SPD
127     1138       033 50.480 N   118 20.305 W    -0011.   0.000    0.000

ITER    ELEV    GEOM    SAT
02      45      N-W     7462.25
```

Figure 4-8. Typical NAVSAT Output Data Printout.

4.2 Continued.

comparative data from the double whip antenna path. Figure 4-9 shows the results for the VPA averaged over 28 passes. The high channel (400 MHz) was improved by 10 percent, while the low channel (150 MHz) remained virtually unchanged. The 10 percent increase in the 400 MHz reception could be accounted for in the better test setup or in the final configuration of the VPA within the omni antenna. Problems with the low band reception are discussed in subsection 6.2.

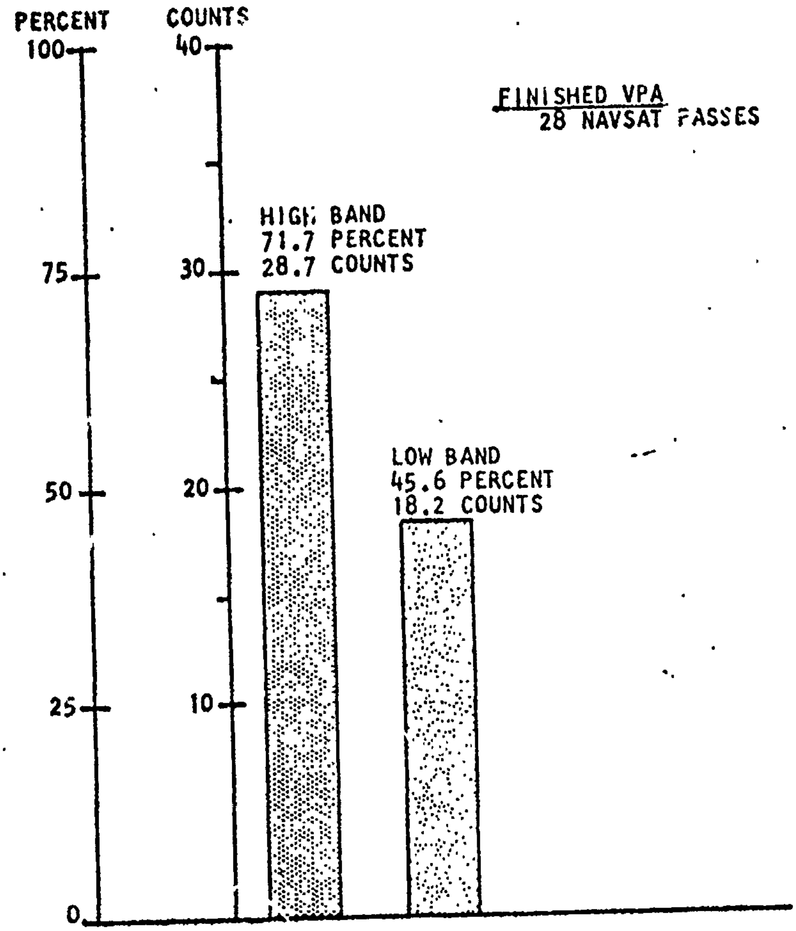


Figure 4-9. Data for Finished VPA for 28 NAVSAT Passes.

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Section 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 AMPLIFIER UNIT.

The circuit described in subsection 2.2 meets all the performance specifications, consisting of bandwidth, sensitivity, and size requirements. The noise figure of the amplifier is the one area where further effort could be expended. The FET input stage is the limiting factor in achieving both broadband performance and a low noise figure, and future development of VPA amplifiers should start with the investigation of new devices. Particular attention should be given to investigating the new gallium-arsenide FET that is under development for use at microwave frequencies. With such a device, noise figures of 3 dB and high performance beyond 500 MHz should be easily realized.

6.2 ANTENNA ELEMENT.

It was noticed during several of the pattern/gain tests that at times the data did not correlate with previous measured data and that there were sometimes large jumps in gain from one test to another. This was especially noticeable around 150 MHz, since much of the testing was at this frequency. Further investigation with the antenna unit out of the radome housing showed that these jumps could be caused by exerting pressure on the biconical antennas (compression, expansion, or side pressure). The investigation revealed that the 175 to 180 MHz band was the region most seriously affected. It so happened that, at the time of these measurements, the biconical antennas were not terminated. When a 50-ohm termination was placed on the output connector of the low band biconical, the large jumps in gain ceased to occur and, instead, there were only small changes. The high band antenna cannot be terminated in the same manner because its output goes directly into a waveguide filter and is detected there.

After several further tests, the following conclusions were reached.

a. Because the biconical antennas are in the near field of the VPA (and vice versa), they have a definite effect on the performance of the VPA.

6.2 Continued.

b. When the low band biconical was unterminated, any signal received by the biconical was reflected and reradiated. The specific amplitude and phase of that reradiated signal determines the effect of the biconical antenna on the VPA.

c. A change in physical configuration of the biconical, as caused by different physical pressures, can change this amplitude and phase and, thus, can cause jumps in the VPA signal. The frequency range where this effect is the worst is 175 to 180 MHz. Since this biconical antenna will, in fact, be terminated at all times when the unit is installed in the system, the gain jumping effect will be diminished. However, because the basic cause of the problem still remains, the performance of the VPA in this general frequency band will be somewhat deteriorated from the expected performance.

6.3 GENERAL COMMENTS.

It should be noted that, while the performance of the VPA for NAVSAT reception at 150 MHz was less than expected, the tests were conducted (at Magnavox) under less than ideal conditions. It is strongly recommended that extensive tests be conducted after VPA installation on the vehicle. These tests should be at various heights, starting at 2 feet above the water surface, in order to note the ground plane effect on antenna pattern.

Second, it should be noted that the general performance of the VPA greatly exceeds the gain of the present sleeve antenna across the frequency band for general communications reception.

6.4 HIGH POWER CONSIDERATIONS.

APPENDIX A

ANTENNA TEST PATTERNS

APPENDIX A

ANTENNA TEST PATTERNS

The following graphs are the results of the EBARF range elevation and conical pattern testing of the VPA. Figure A-1 through A-11 are elevation tests, while Figures A-12 through A-21 are conical patterns. Patterns for cut dipoles are shown as standards. See Figures 4-1, 4-2, and 4-3 for the range test apparatus.

ANTENNA VPA PROTOTYPE SN-33

FREQ. 80 mhz

PATTERN EL

Bottom of Radome housing 22" above water.

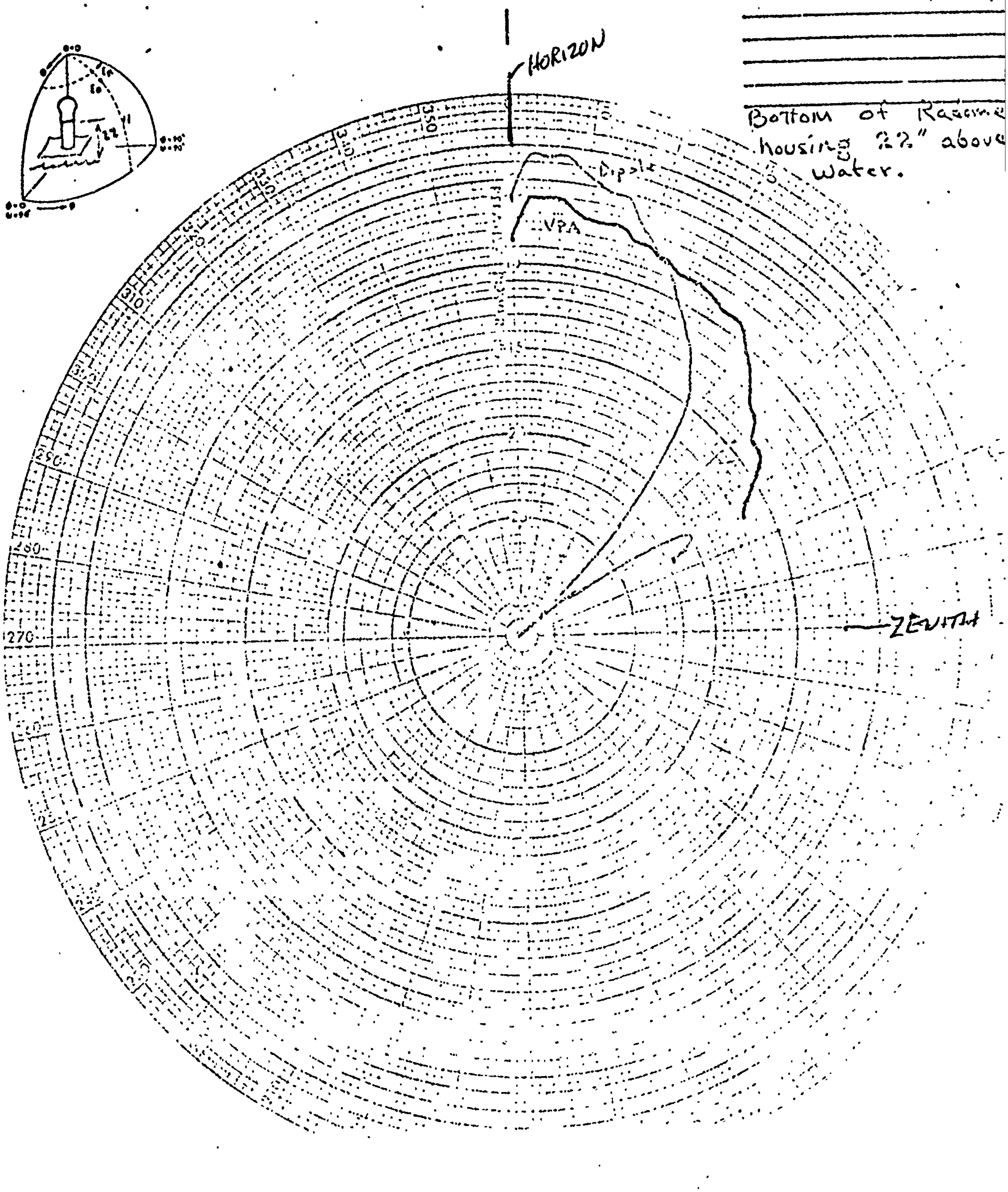

Figure A-1. Antenna Elevation Pattern: 80 MHz.

PROJECT:	ENGR:	TECH:	DATE
335	HH	TK	

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ANTENNA POLAR PATTERN-32 db RANGE

ANTENNA VPA PROTOTYPE SII-33

FREQ. 150 mhz

PATTERN EL

Bottom of housing 2? above water

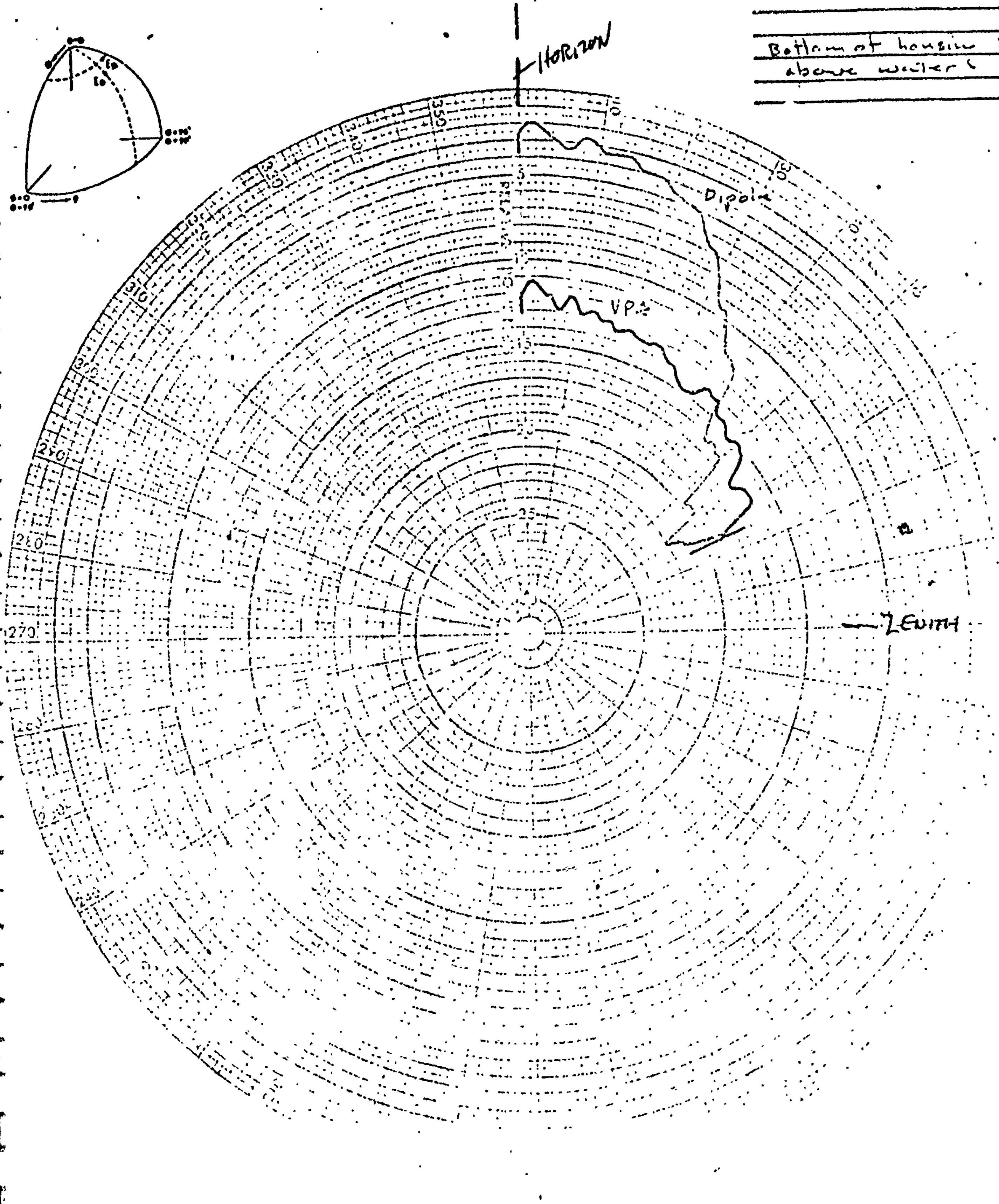

Figure A-2. Antenna Elevation Pattern: 150 MHz.

PROJECT:	ENGR:	TECH	DATE
[illegible]	[illegible]	[illegible]	[illegible]

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ANTENNA POLAR PATTERN-32 db RANGE

ANTENNA VPA PROTOTYPE SN-33

FREQ. 200 mhz

PATTERN EL

Bottom of [illegible] above water

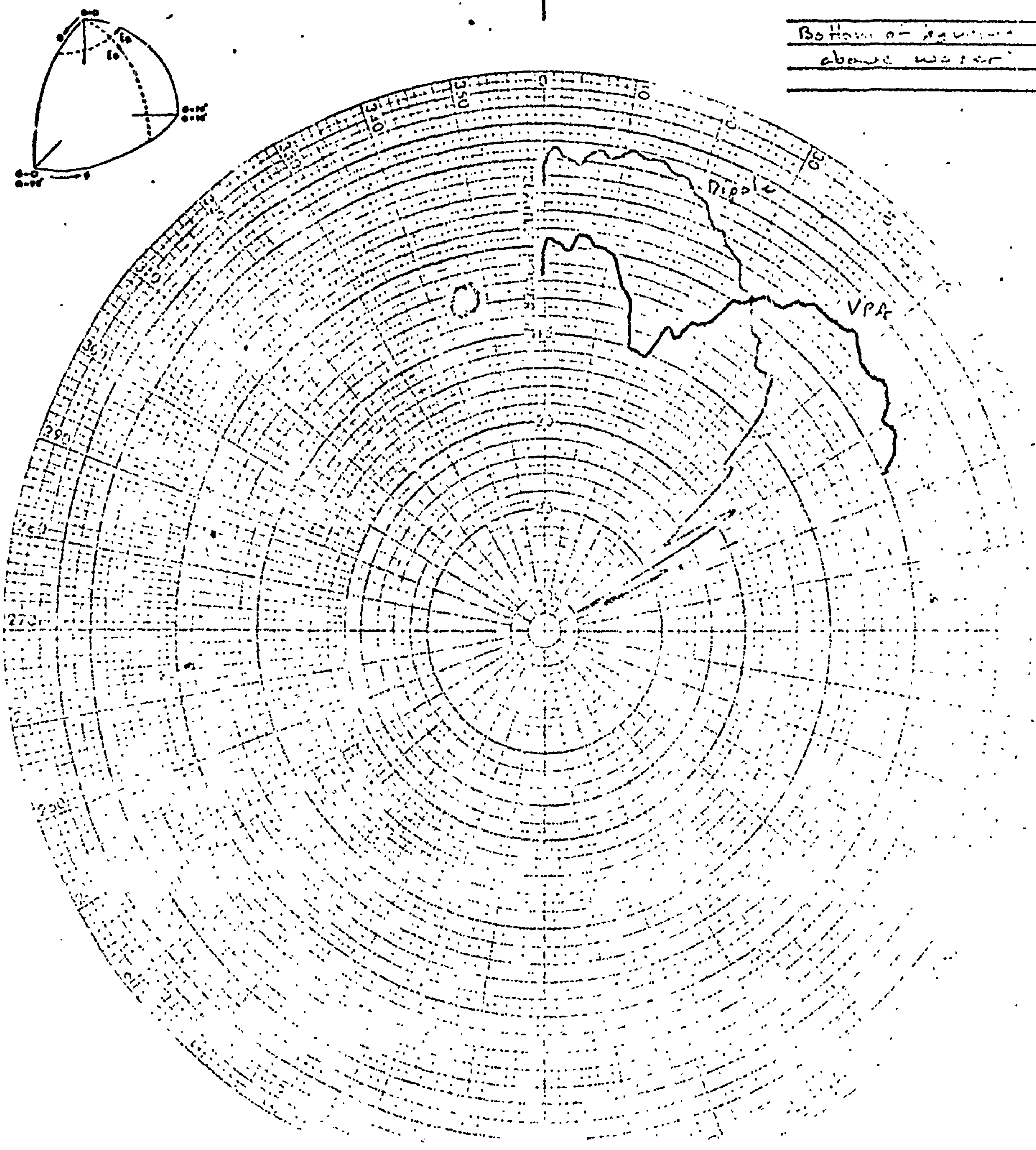

Figure A-3. Antenna Elevation Pattern: 200 MHz.

PROJECT:	ENGR:	TECH:	DATE:
335	HH	TK	2 [illegible]

SYLVANIA

ANTENNA POLAR PATTERN-32 db RANGE

ANTENNA VPA PROTOTYPE SN-33

FREQ. 250 mhz

PATTERN EL

Bottom of housing ... above water

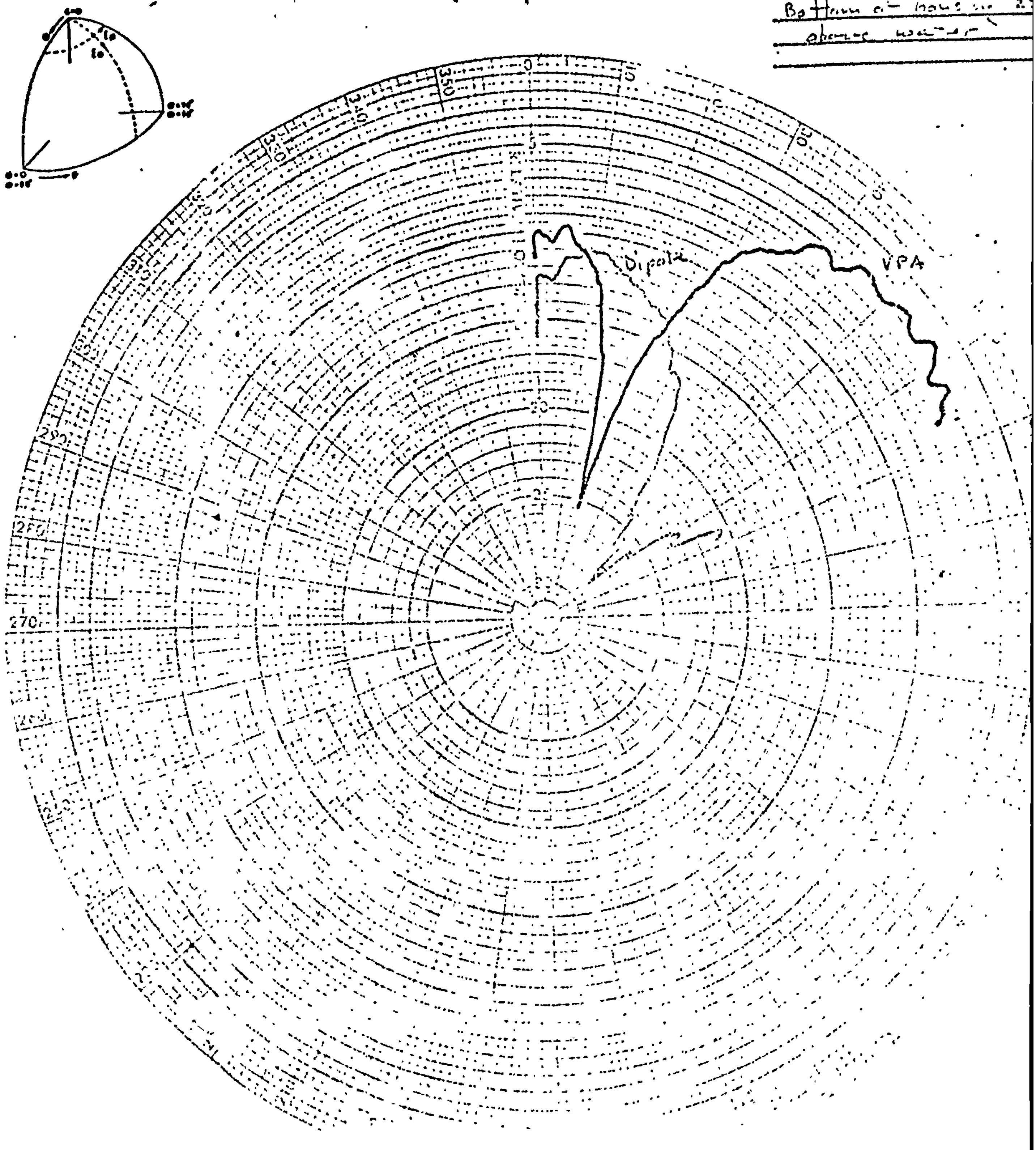

Figure A-4. Antenna Elevation Pattern: 250 MHz.

PROJECT:	ENGR:	TECH.	DATE
325	HT	TK	

SYLVANIA ELECTRONIC SYSTEMS

MOUNTAIN VIEW, CALIF.

ANTENNA VPA PROTOTYPE SN-33

FREQ. 300 mhz

PATTERN El ‖

Bottom of housing
above water

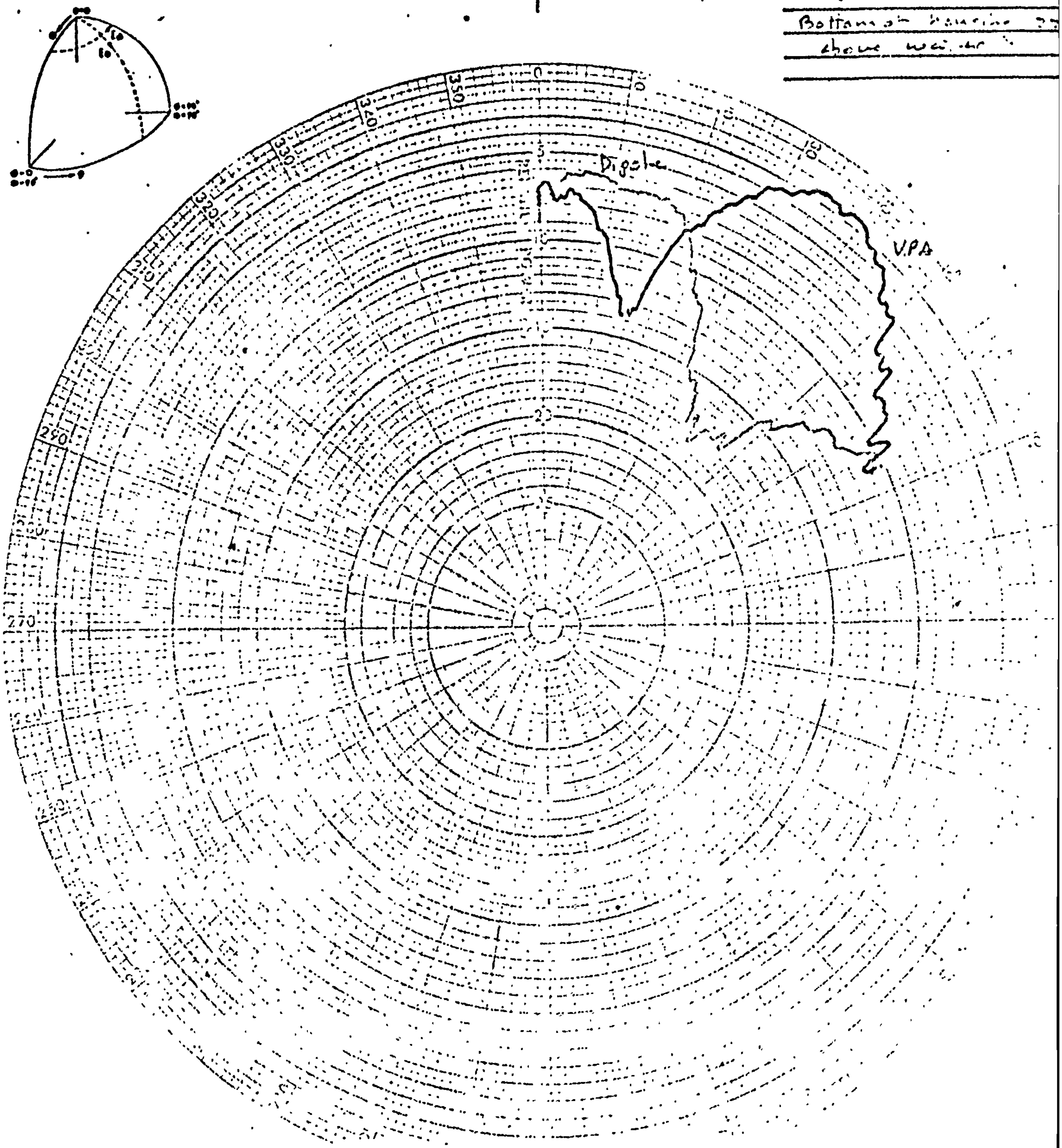

Figure A-5. Antenna Elevation Pattern: 300 MHz

PROJECT:	ENGR:	TECH:	DATE:
335	HH	TK	[illegible]

SES-W-3104 (3-68)

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ANTENNA VPA PROTOTYPE SN-33

FREQ. 350 mhz
PATTERN EL

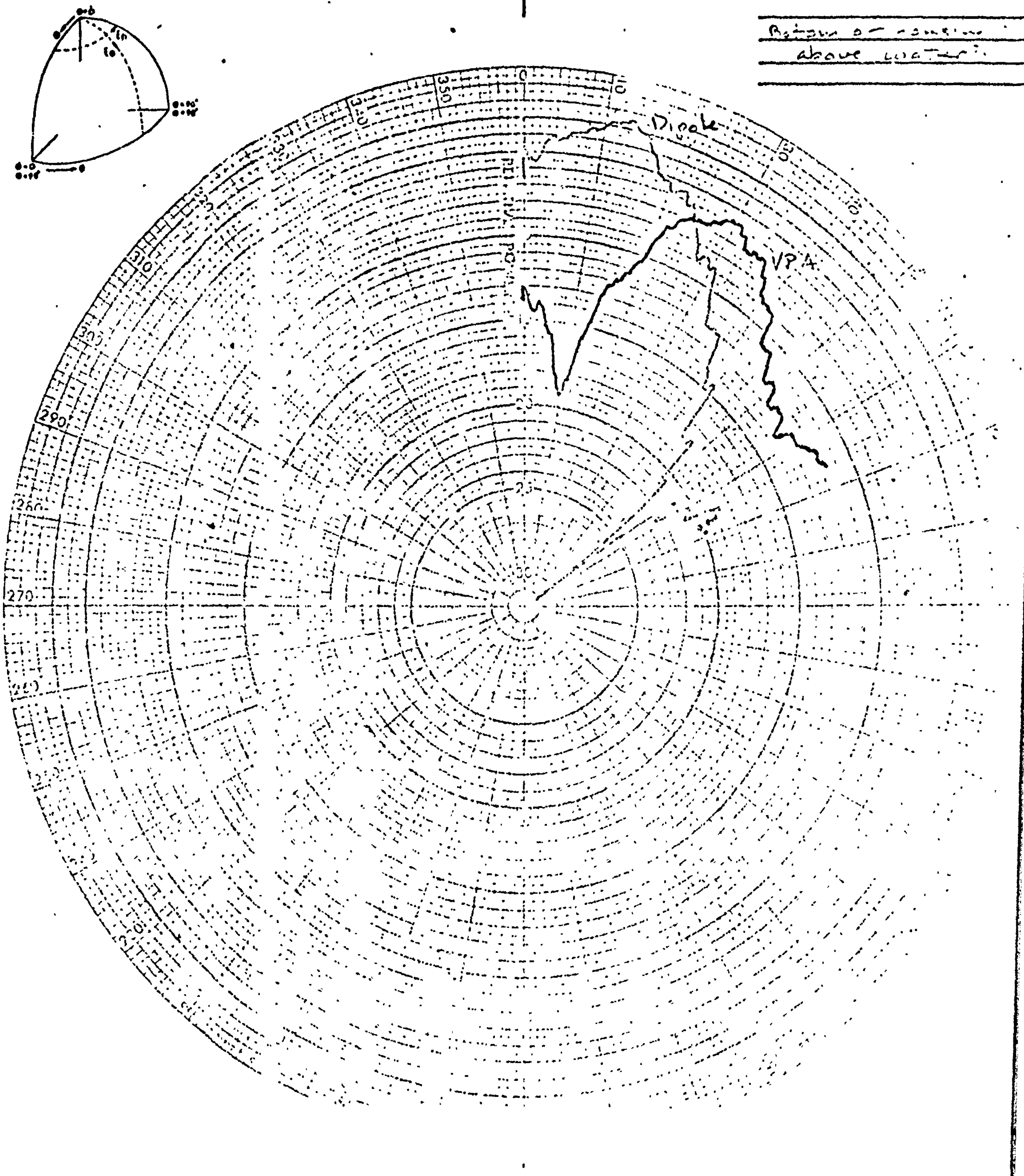

Figure A-6. Antenna Elevation Pattern: 350 MHz.

PROJECT:	ENGR:	TECH.	DATE:
335	H	TK	[illegible]

SES-W-3104 (3-66)

ANTENNA VPA PROTOTYPE SN-33

FREQ. 400 mhz

PATTERN EL

Bottom of housing ... above water

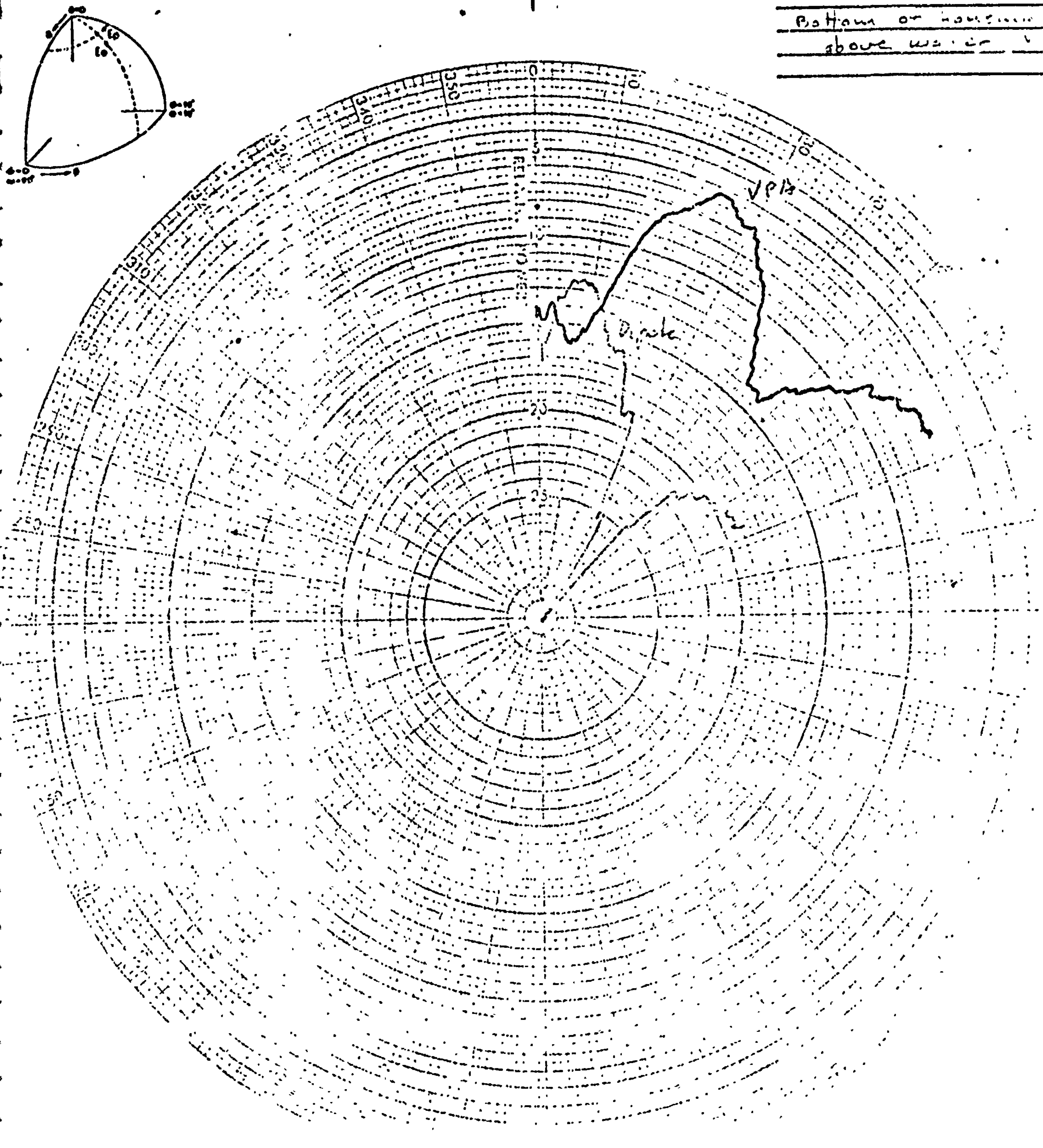

Figure A-7. Antenna Elevation Pattern: 400 MHz.

PROJECT:	ENGR:	TECH:	DATE
335	HH	TK	

SYLVANIA ELECTRONIC SYSTEMS

ANTENNA VPA PROTOTYPE SN-33

FREQ. 450 mh

PATTERN EL

Pattern of housing above the roof

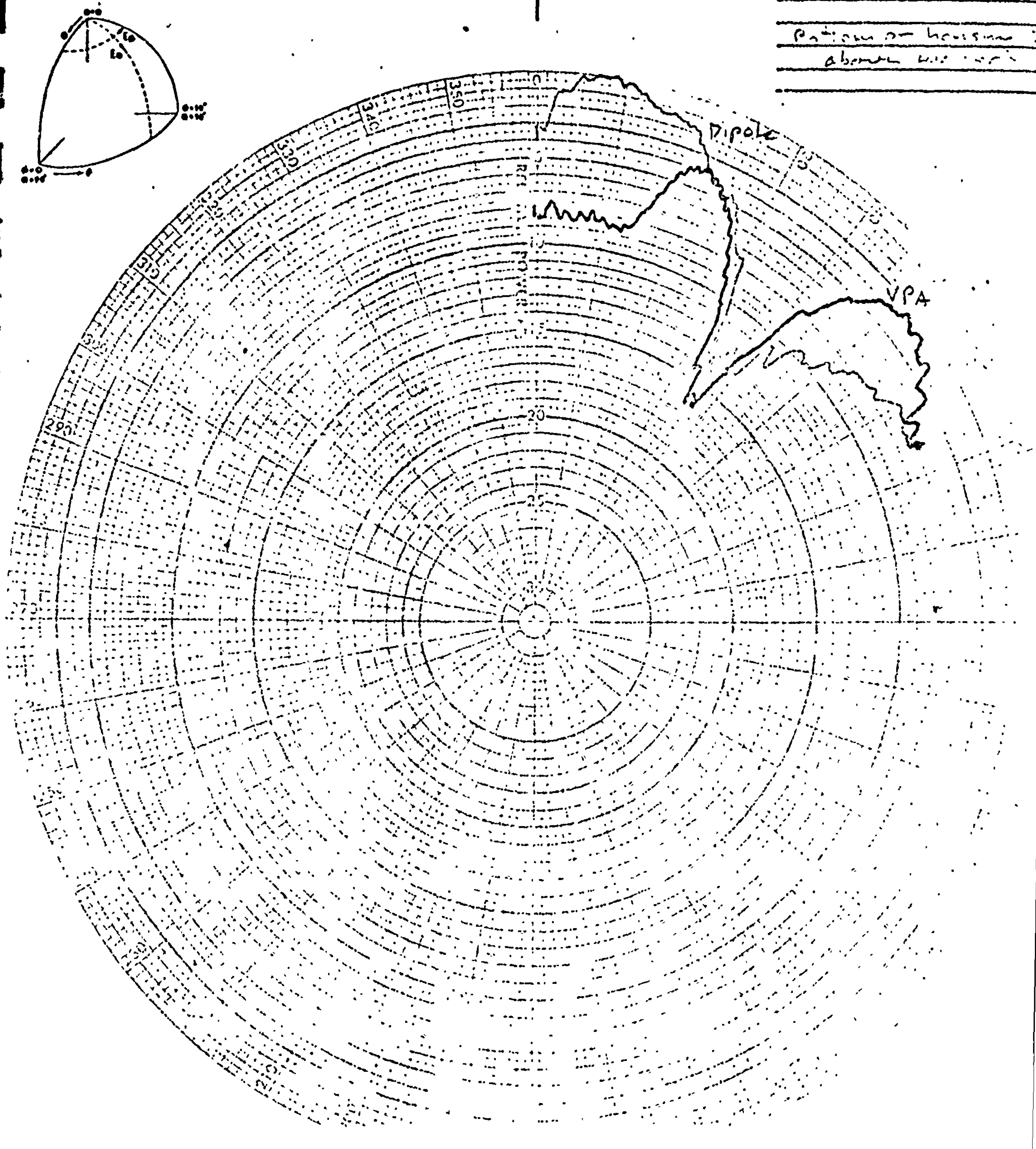

Figure A-8. Antenna Elevation Pattern: 450 MHz.

PROJECT:	ENGR:	TECH:	DATE:
335	HH	TK	2 [illegible]

SES-W-1104 (3-63)

ANTENNA VPA PROTOTYPE SN-33 FREQ. 500MHz
PATTERN EL

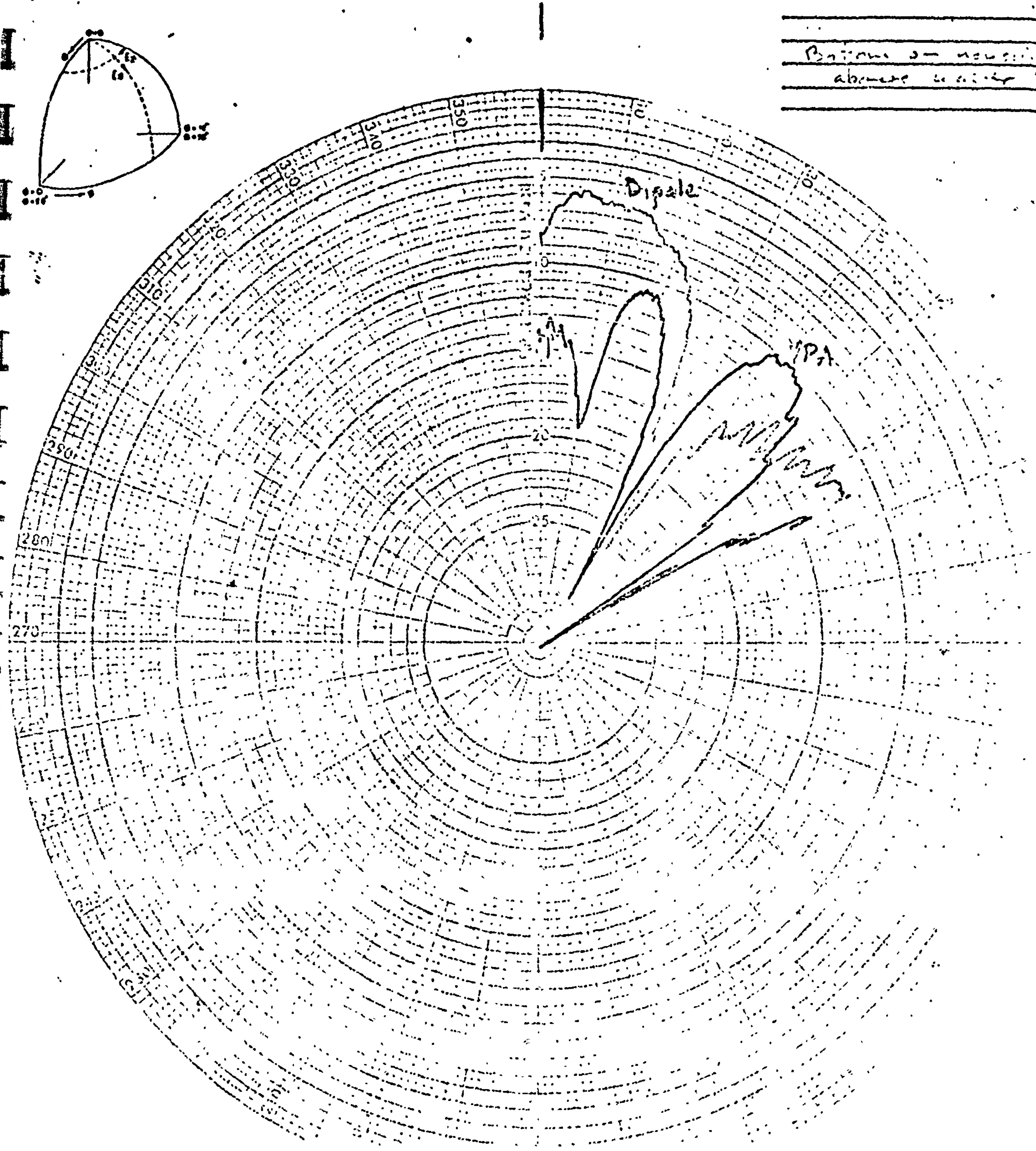

Figure A-9. Antenna Elevation Pattern: 500 MHz.

PROJECT:	ENGR:	TECH.	DATE
335	HH	TK	

SYLVANIA SYLVANIA ELECTRONIC SYSTEMS

MOUNTAIN VIEW, CALIF.

ANTENNA POLAR PATTERN

ANTENNA VPA Prototype S/N 33 Retest

FREQ. 150 MHz

PATTERN Elev

Bottom of housing above water

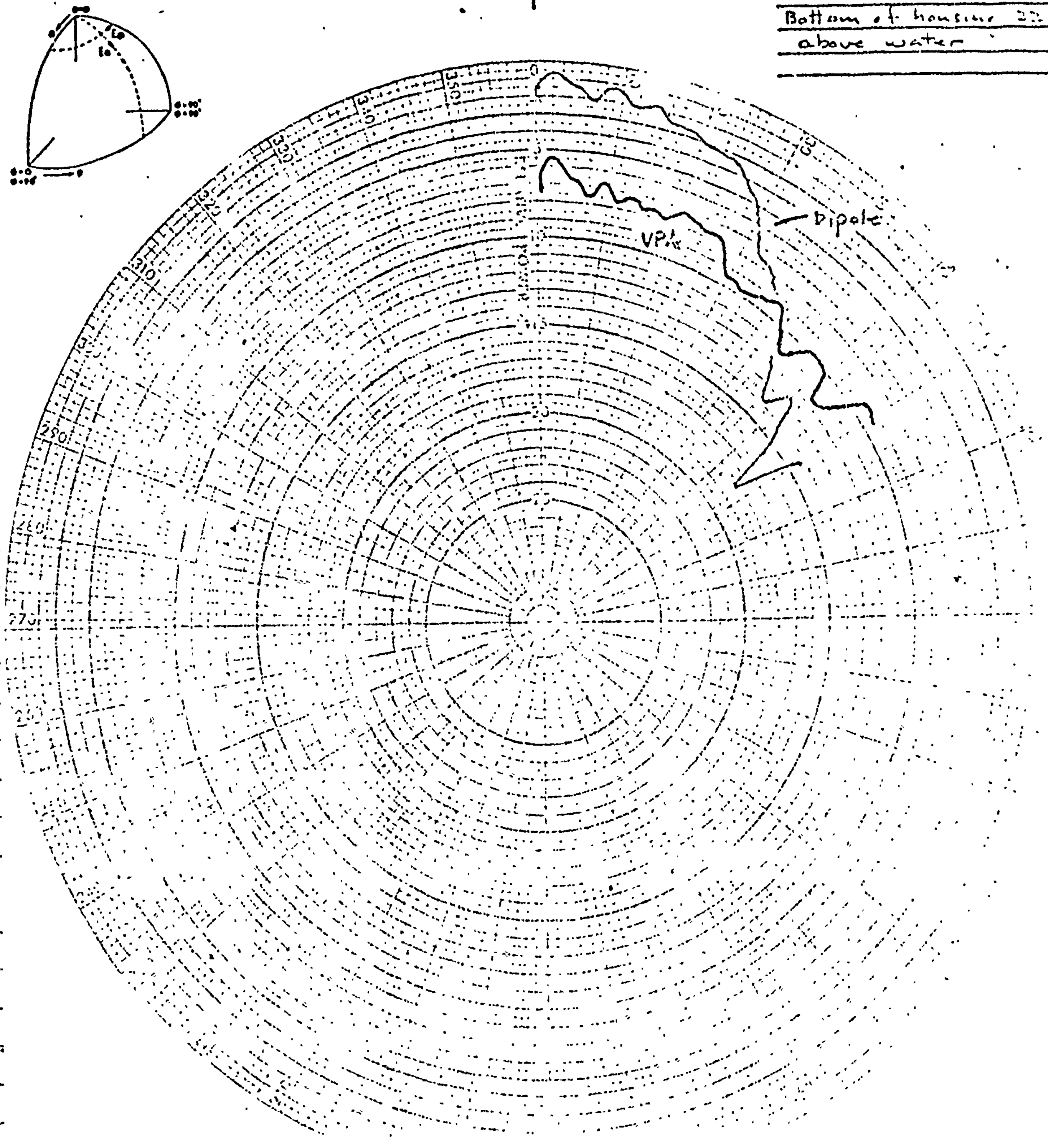

Figure A-10. Antenna Elevation Pattern Retest: 150 MHz.

PROJECT:	ENGR:	TECH:	DATE:

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ANTENNA POLAR PATTERN-32 db RANGE

ANTENNA VPA Prototype S/N 33
Retest

FREQ. 400 MHz
PATTERN EHU

Bottom of housing 77"
above water

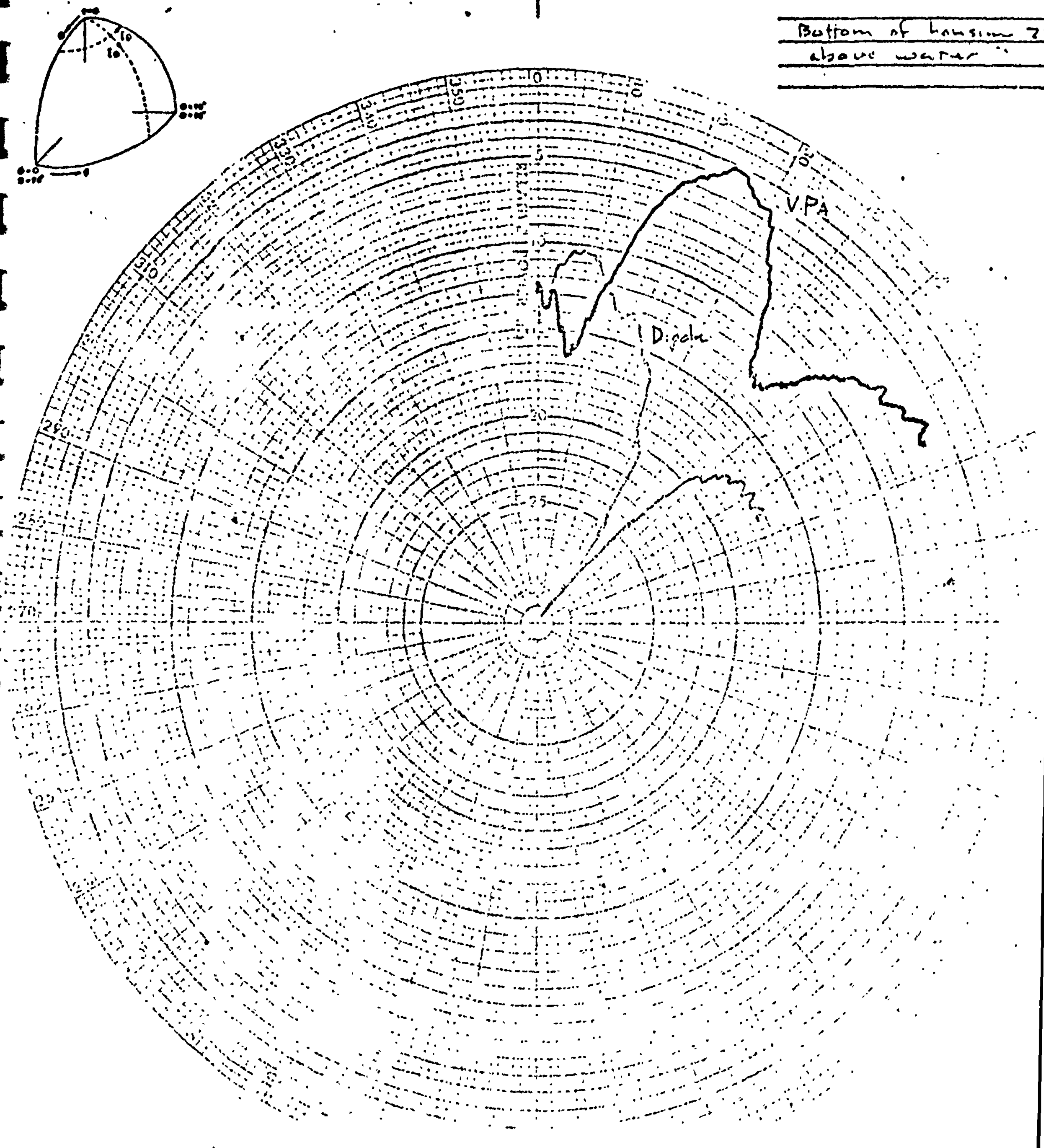

Figure A-11. Antenna Elevation Pattern Retest: 400 MHz.

PROJECT:	ENGR:	TECH.	DATE:
335	Hochman		5/1

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ANTENNA VPA PROTOTYPE SN-33

FREQ. 150 mhz

PATTERN CONIC

@ 10° Elev.

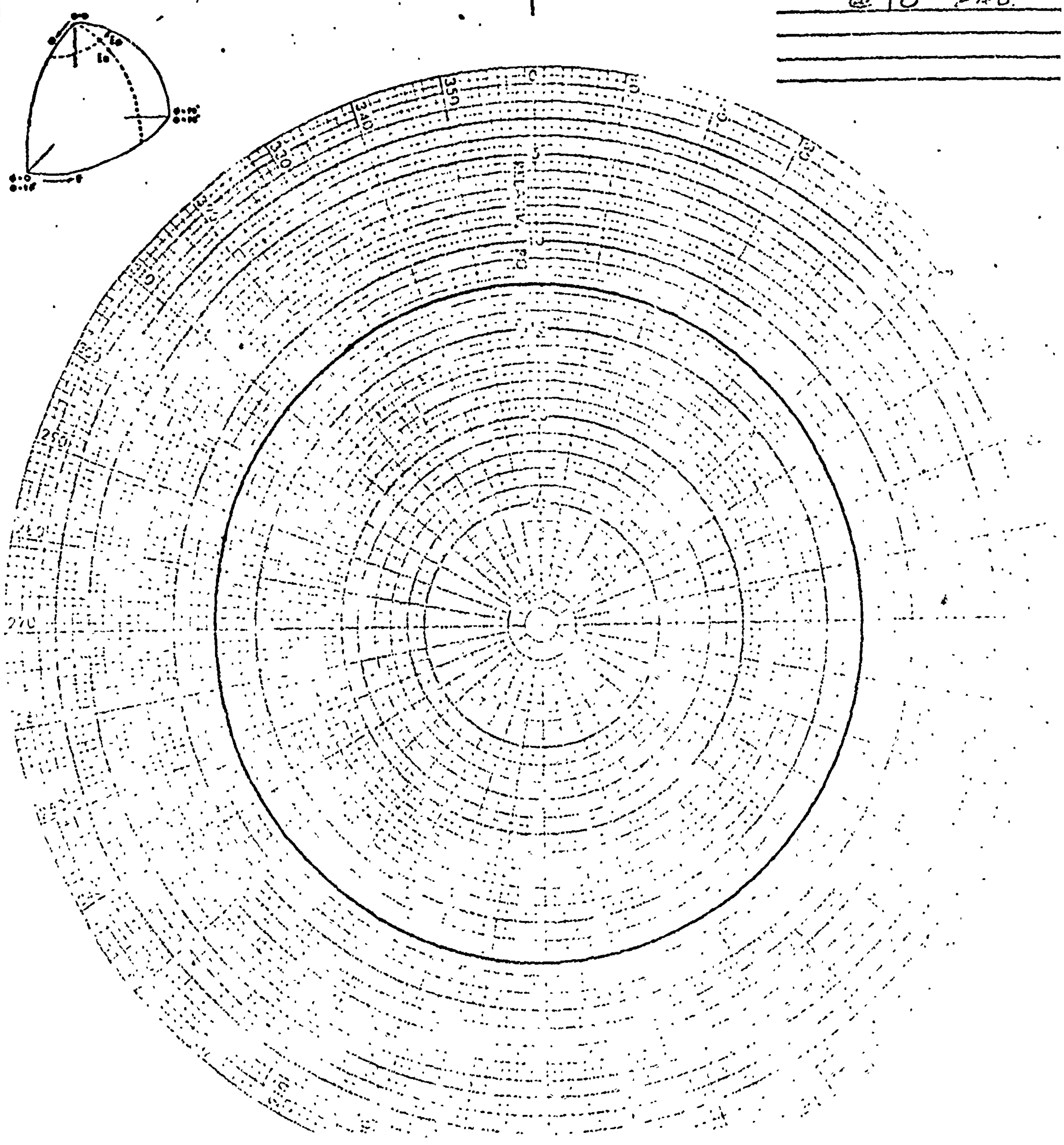

Figure A-12. Antenna Conical Pattern: 150 MHz at 10-Degree Elevation.

PROJECT:	ENGR:	TECH:	DATE:
335	HH	TK	2

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ANTENNA POLAR PATTERN-32 db RANGE

ANTENNA VPA PROTOTYPE SN-33

FREQ. 150 mhz

PATTERN Conic

@ 30° Elev.

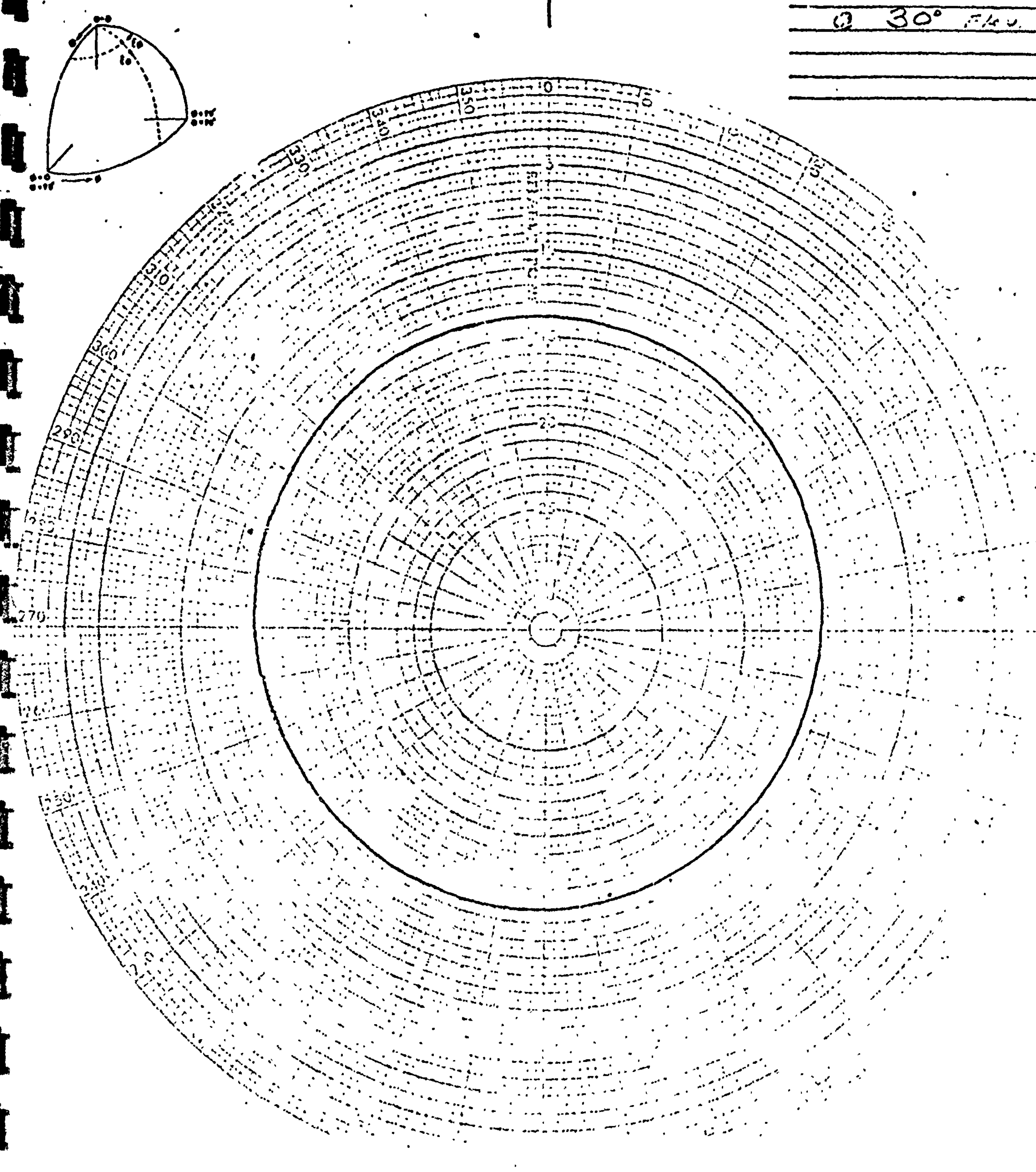

Figure A-13. Antenna Conical Pattern: 150 MHz at 30-Degree Elevation.

PROJECT:	ENGR:	TECH:	DATE
335	HH	TK	[illegible]

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ANTENNA VPA PROTOTYPE

FREQ. 200 mhz

PATTERN Conic

@ 10° Elev

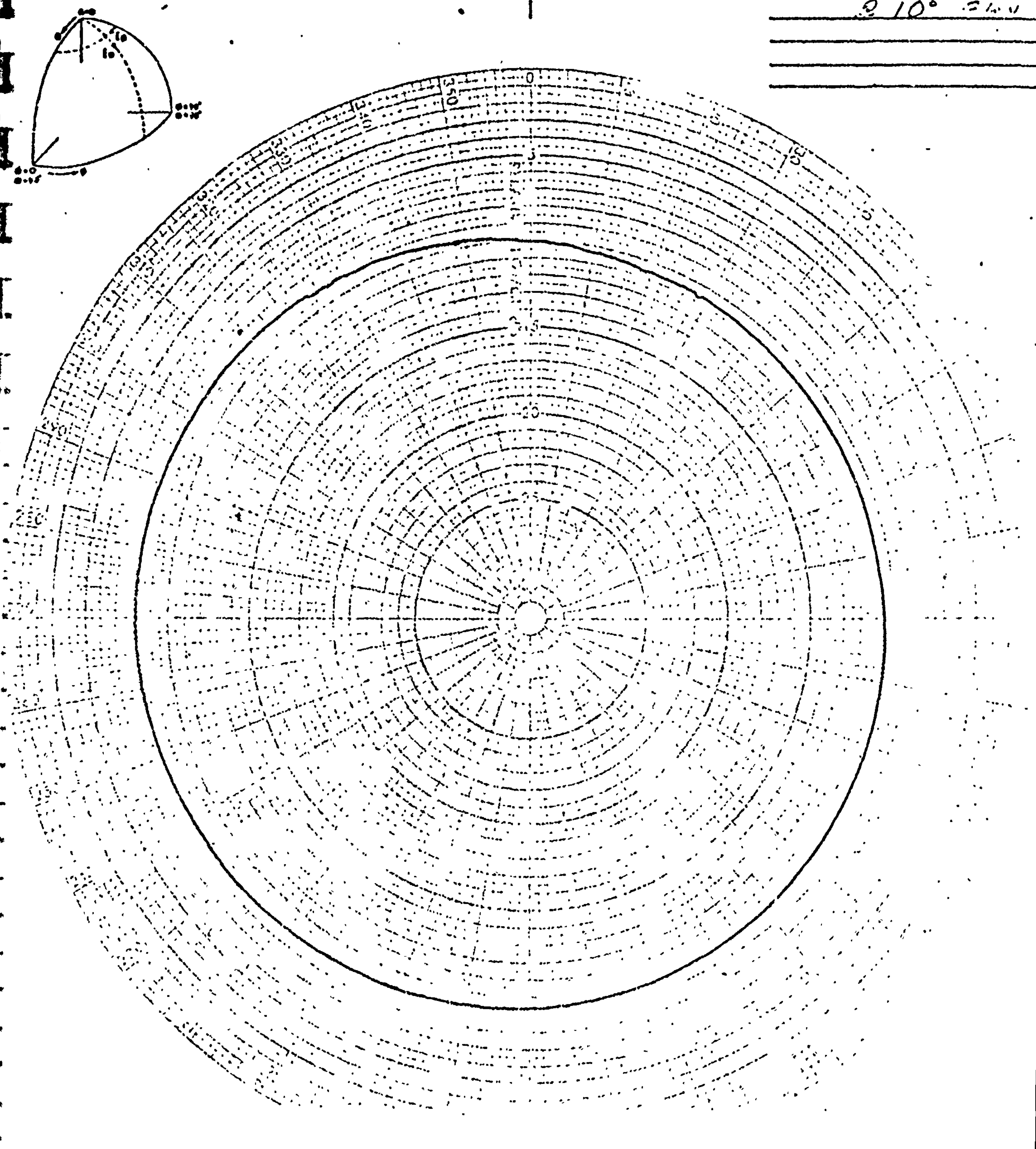

Figure A-14. Antenna Conical Pattern: 200 MHz at 10-Degree Elevation.

PROJECT	ENGR:	TECH:	DATE:
335	HH	TK	[illegible]

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SYLVANIA ELECTRONIC SYSTEMS

ANTENNA POLAR PATTERN-32 dB RANGE

ANTENNA VPA PROTOTYPE SN-33

FREQ. 200 mhz

PATTERN Conic

(3) 30° Elev.

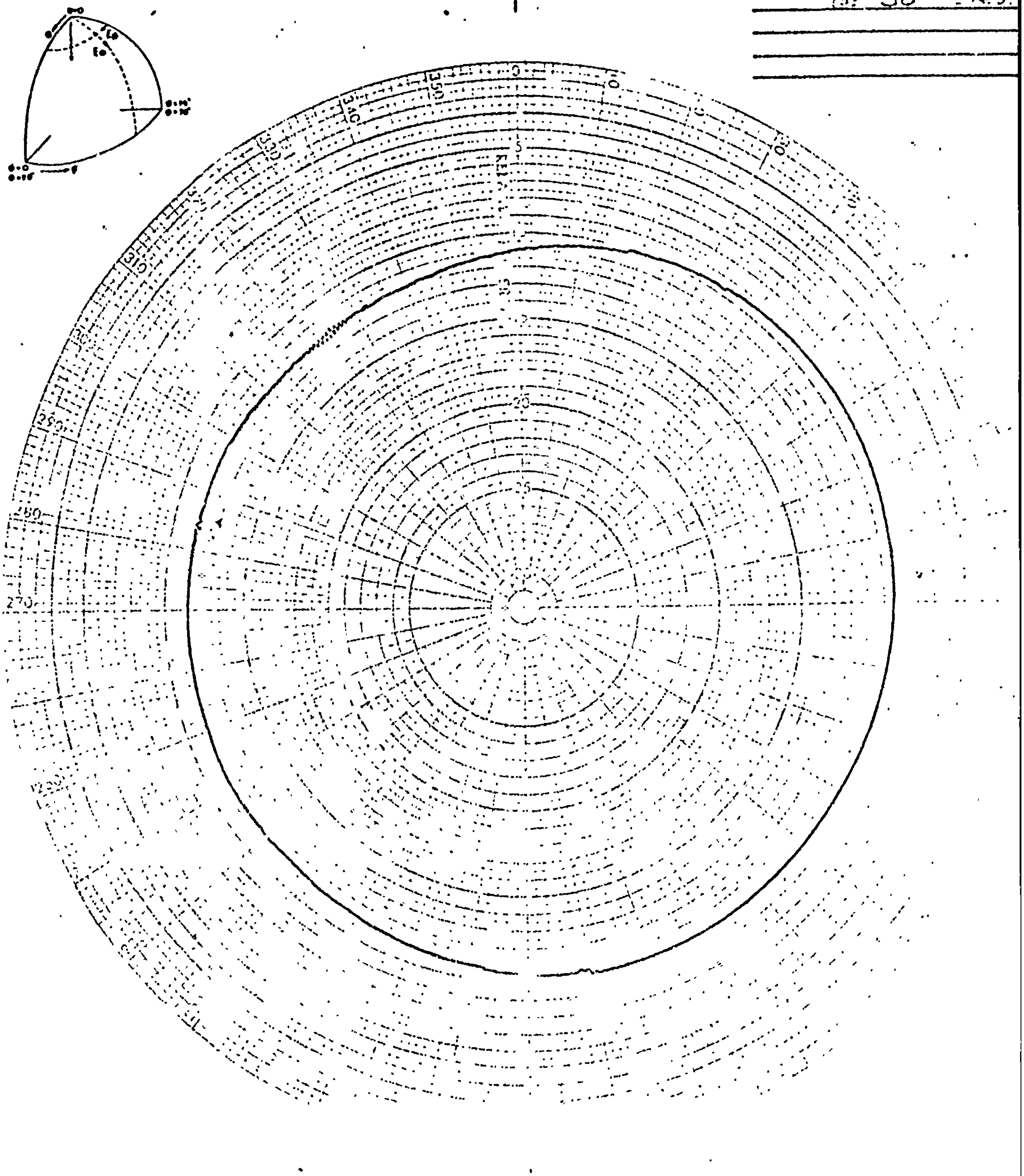

Figure A-15. Antenna Conical Pattern: 200 MHz at 30-Degree Elevation.

PROJECT:	ENGR:	TECH:	DATE:
335			

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ANTENNA POLAR PATTERN-32 db RANGE

ANTENNA VPA PROTOTYPE SN-33

FREQ. 300 mhz

PATTERN Conic

@10° Elev

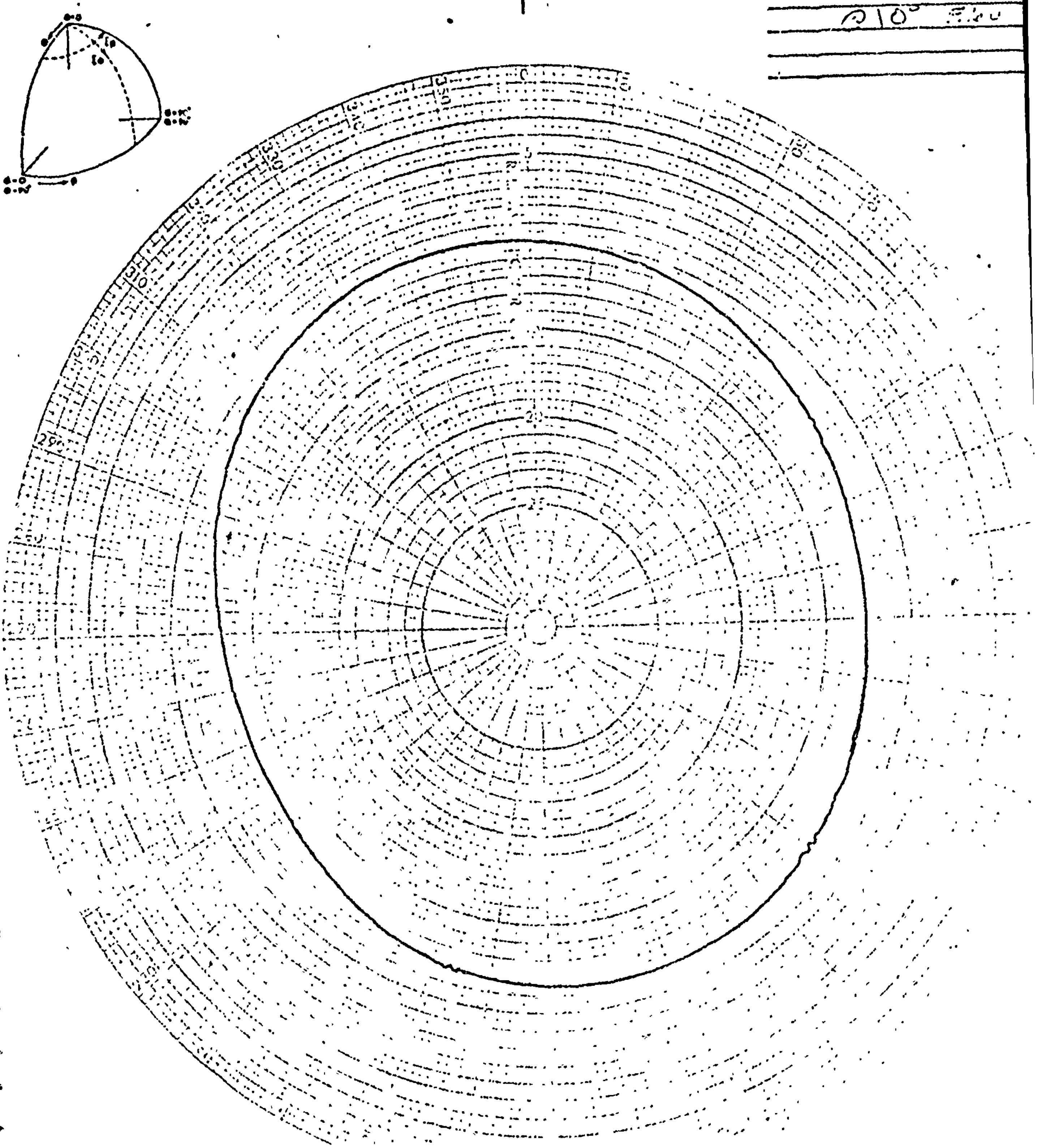

Figure A-16. Antenna Conical Pattern: 300 MHz at 10-Degree Elevation.

PROJECT:	ENGR:	TECH.	DATE:
335	HH	TK	

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SYLVANIA ELECTRONIC SYSTEMS

ANTENNA POLAR PATTERN-32 db RANGE

ANTENNA VPA PROTOTYPE SN-33

FREQ. 300 mhz

PATTERN Conic

@ 30° Elev.

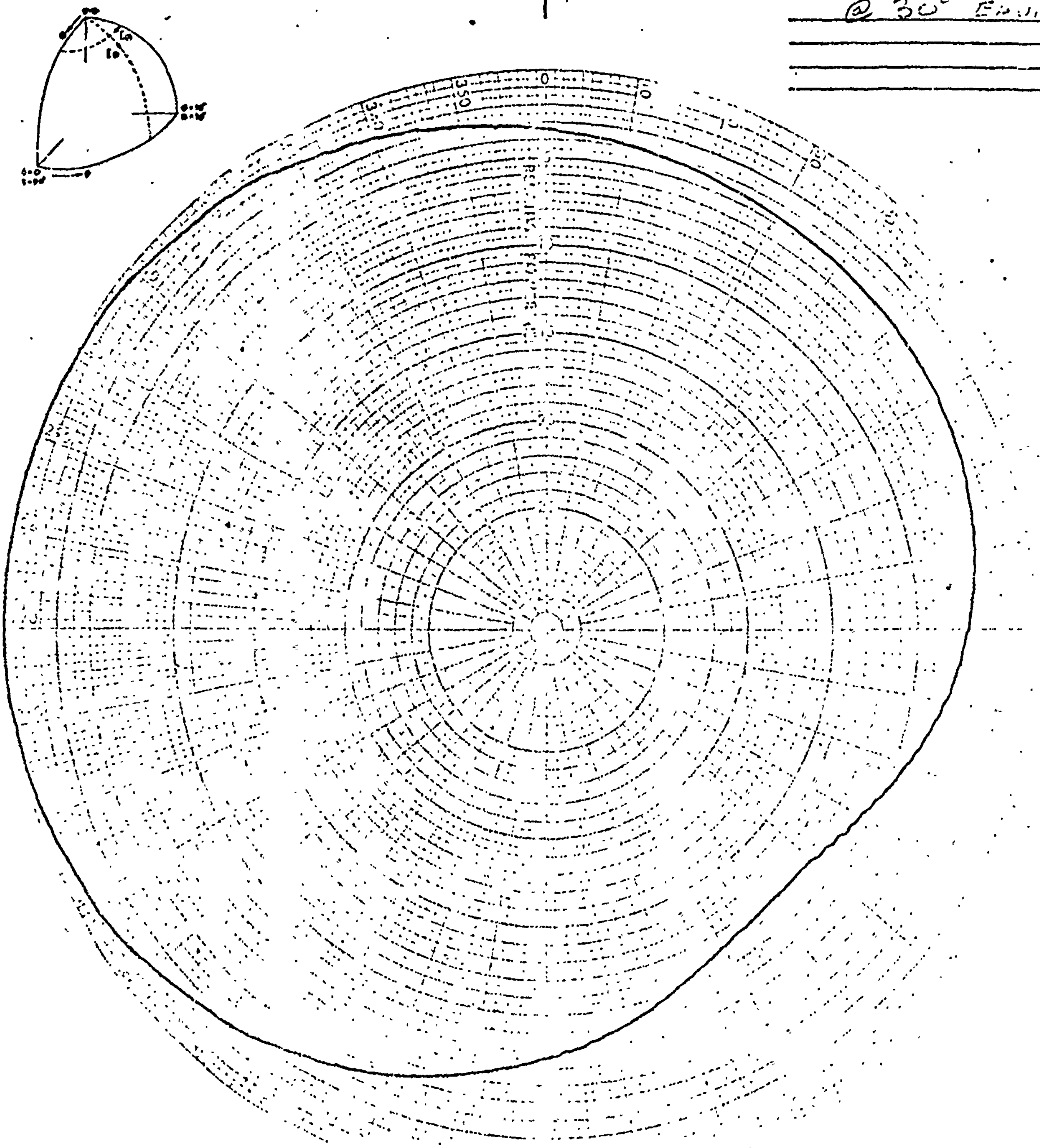

Figure A-17. Antenna Conical Pattern: 300 MHz at 30-Degree Elevation.

PROJECT:	ENGR:	TECH:	DATE:
335	HH	TK	[illegible]

SYLVANIA ELECTRONIC SYSTEMS

ANTENNA VPA PROTOTYPE SM-33

FREQ. 400 mhz
PATTERN CONIC
15° EL

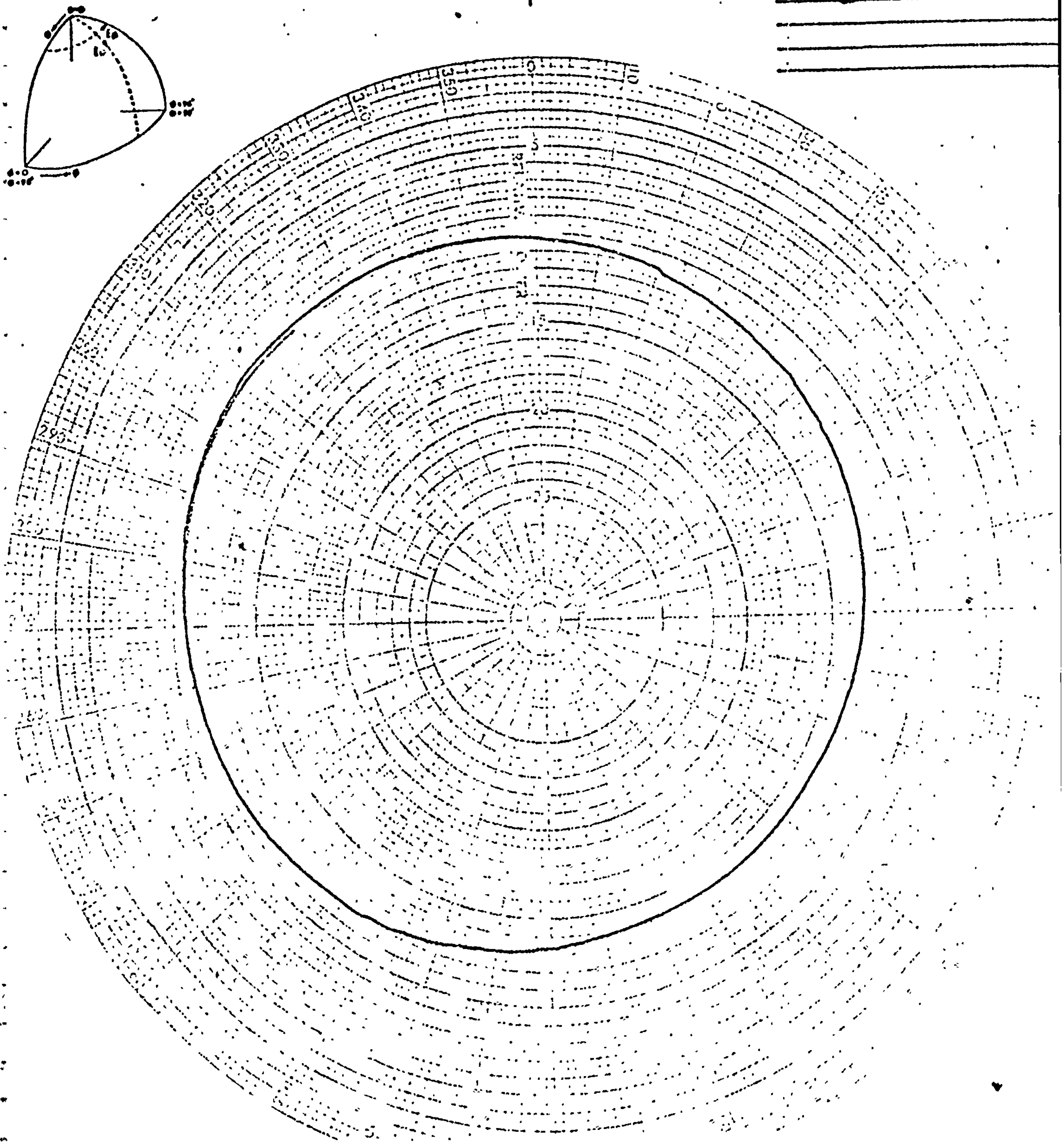

Figure A-18. Antenna Conical Pattern: 400 MHz at 15-Degree Elevation.

PROJECT:	ENGR:	TECH:	DATE:
335	HH	TK	

ANTENNA VPA PROTOTYPE SN-33
FREQ. 400 mhz
PATTERN CONIC
@ 30°

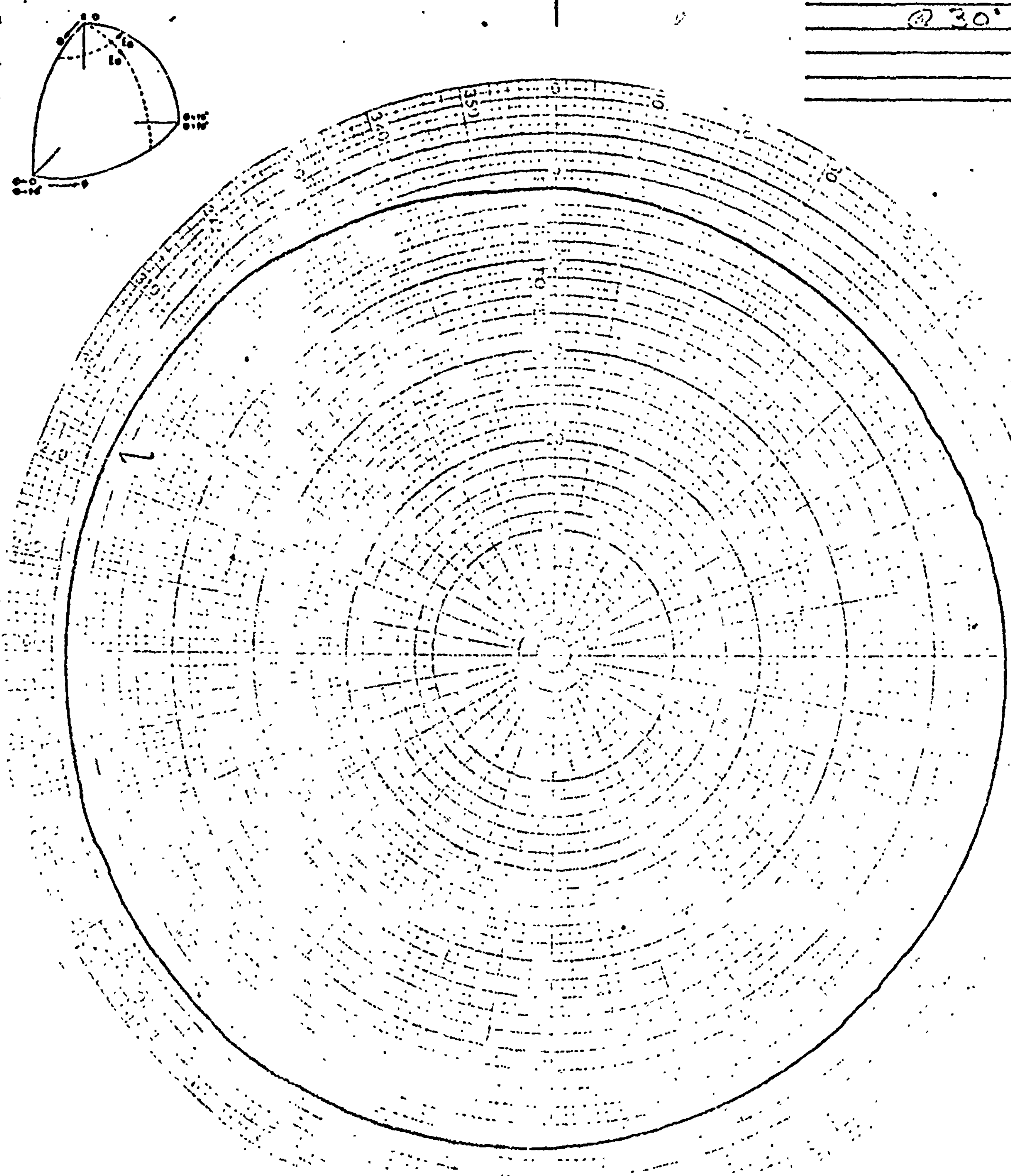

Figure A-19. Antenna Conical Pattern: 400 MHz at 30-Degree Elevation.

PROJECT:	ENGR:	TECH.	DATE.
335	HH		

ANTENNA POLAR PATTERN-52 db RANGE

SYLVANIA ELECTRONIC SYSTEMS

ANTENNA VPA PROTOTYPE SN-33

FREQ. 500 mhz

PATTERN Conical

@ 15° Elev

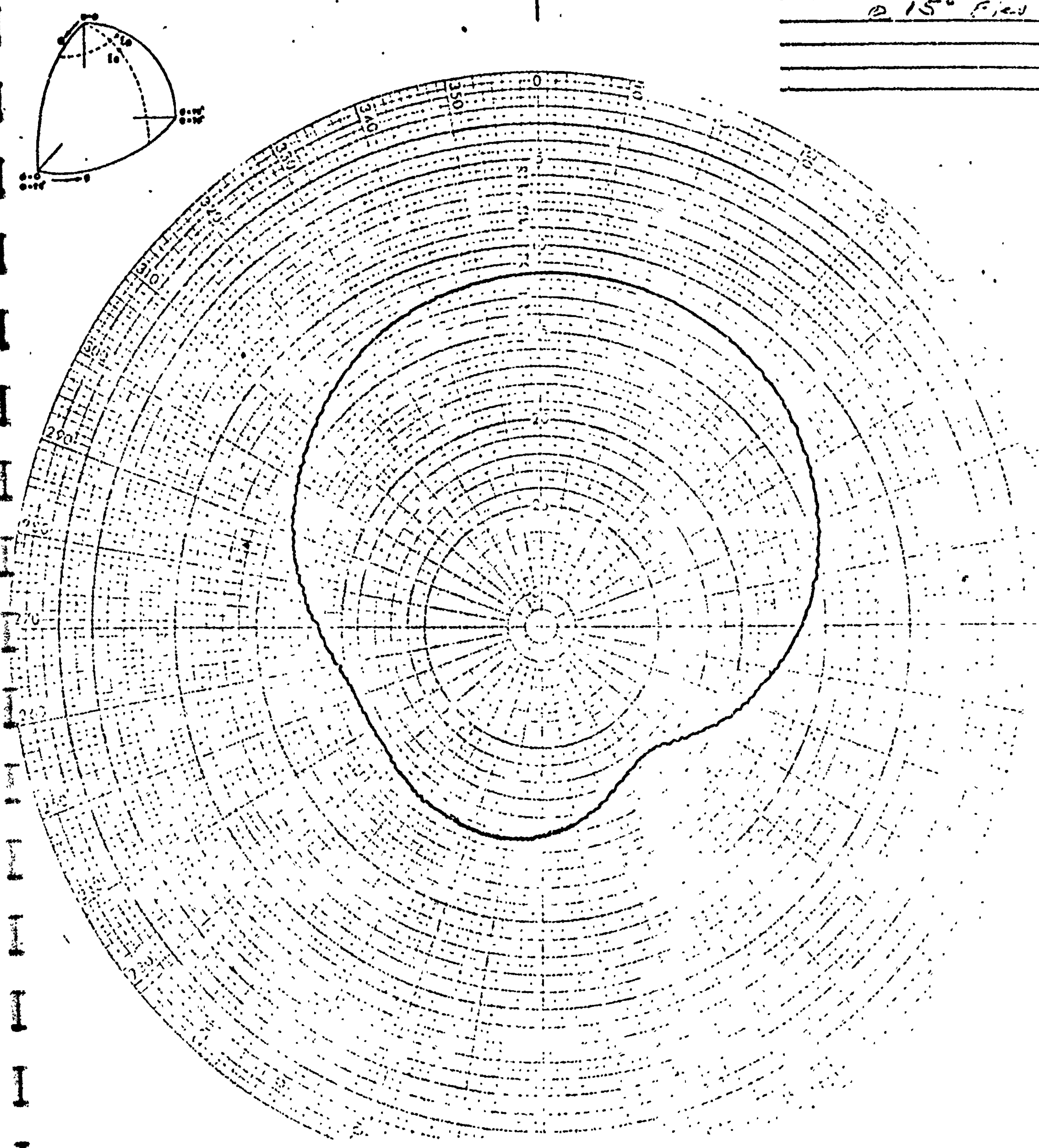

Figure A-20. Antenna Conical Pattern: 500 MHz at 15-Degree Elevation.

PROJECT:	ENGR:	TECH:	DATE:
335	HH	TK	[illegible]

SYLVANIA ELECTRONIC SYSTEMS

ANTENNA POLAR PATTERN-32 db RANGE

ANTENNA VPA PROTOTYPE SN-33

FREQ. 500 mhz

PATTERN Conic

@ 35°

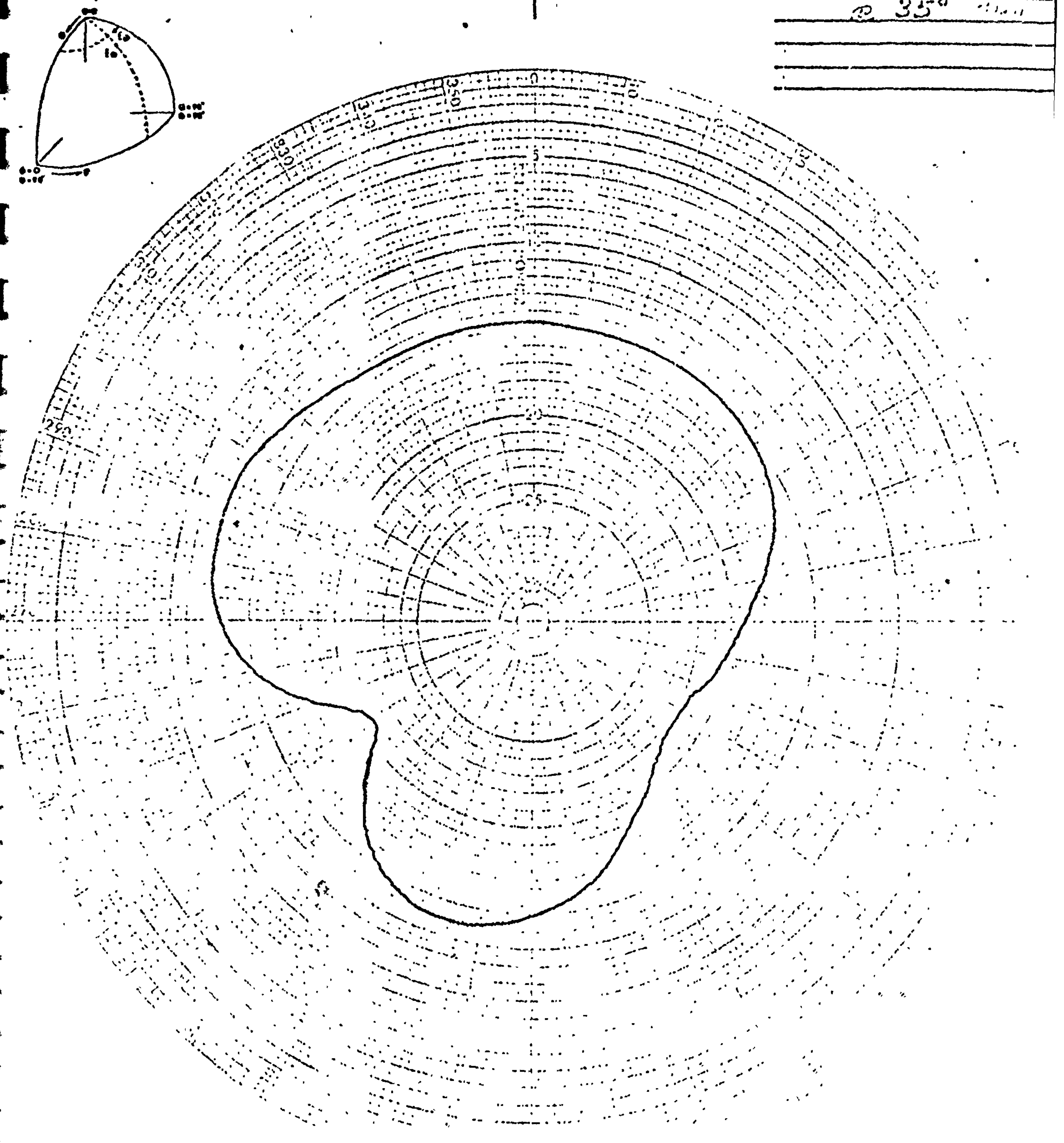

Figure A-21. Antenna Conical Pattern: 500 MHz at 35-Degree Elevation.

PROJECT	ENGR:	TECH:	DATE:
385			

APPENDIX B

TANGENTIAL SENSITIVITY

APPENDIX B

TANGENTIAL SENSITIVITY

Refer to Figure 4-5 in Section 4. The curve represents the field strength (in mV/meter) at the integrated antenna for a receiver system tangential sensitivity* where the receiver does not degrade system noise figure. The tangential sensitivity is given for a system bandwidth of 1 kHz. The test setup used is shown in Figure B-1.

The tangential sensitivities given in the graph can be used to calculate system performance for various bandwidths and for systems in which receiver noise figure does degrade overall performance.

It is known that tangential sensitivity is dependent directly on signal-to-noise ratio and any change in S/N ratio changes the tangential sensitivity on a dB-for-dB basis. This allows the following calculations evolving bandwidth (BW) and receiver noise figure (NF).

For system bandwidths other than 1 kHz,

$$TG_N = (TG_O) \times \sqrt{\frac{BW}{1\ \text{kHz}}}$$

where

TG_N = system tangential sensitivity for arbitrary bandwidth (in μv/m)

TG_O = system tangential sensitivity in 1 kHz bandwidth

BW = arbitrary bandwidth.

Example:

At 500 MHz, TG_N in 100 kHz bandwidth is as follows.

$$TG_N = 9\mu V/m \times \sqrt{\frac{100\ \text{kHz}}{1\ \text{kHz}}} = 90\ \mu V/m.$$

---

* Note: Tangential sensitivity is equivalent to a signal-to-noise ratio of 8 dB.

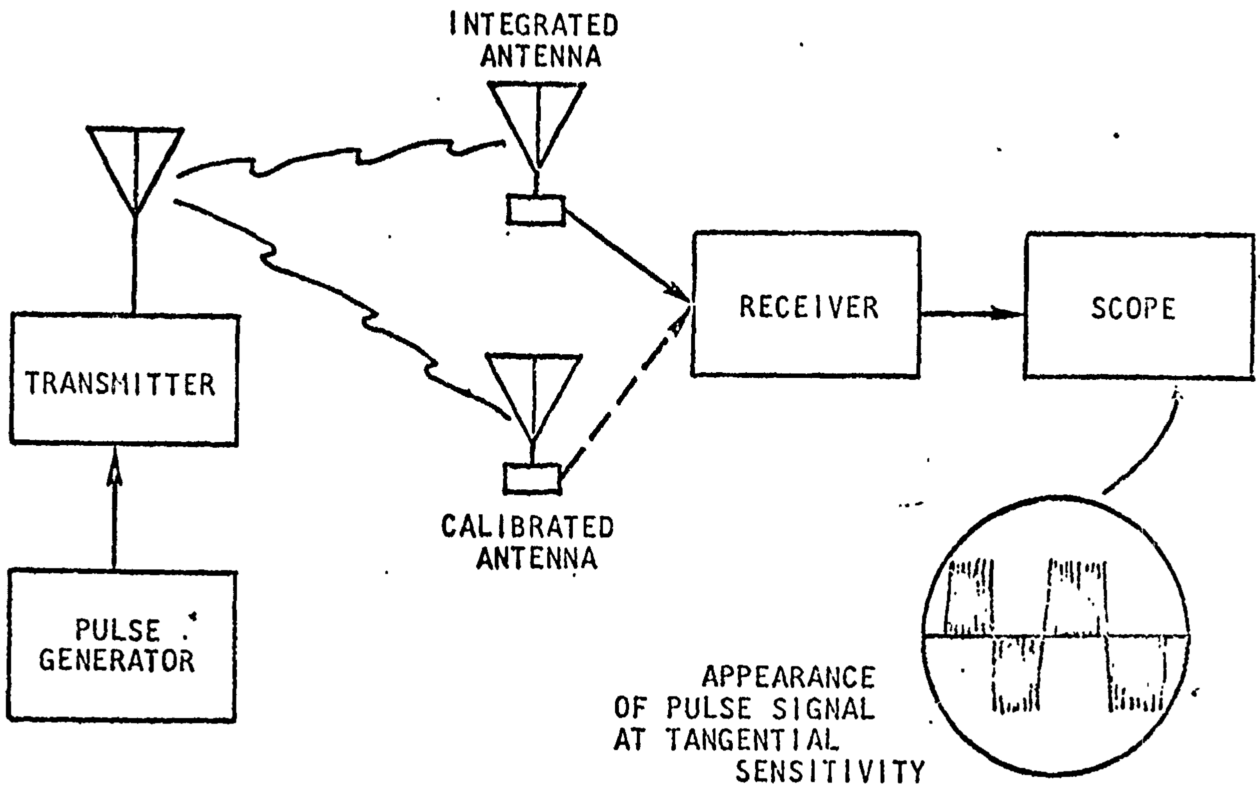

Figure B-1. Tangential Sensitivity Test Setup and Oscilloscope Pattern.

Appendix B. Continued.

Tangential sensitivities for systems where the noise figure following the integrated antenna degrade tangential sensitivity are as follows.

$$TG = TG_{corrected} - NF_A + NF_T \quad \text{(in dB)}$$

where

TG = tangential sensitivity

NF_A = noise figure of VPA

NF_T = total system noise figure.

Also,

$$NF_T = 10 \log \left[F_A + \frac{F_R - 1}{G_A} \right]$$

where

F_A = VPA noise figure expressed as a ratio

F_R = receiver noise figure expressed as a ratio

G_A = VPA power gain expressed as a ratio.

Then

G_A = 12.6. (for the system shown in Table 4-1 of Section 4).

Example:

At 500 MHz using a receiver with a 10-dB noise figure is as follows.

$$TG = 19.9 \text{ dB above } 1\,\mu V/m - 8.9 + 10 \log \left[7.7 + \frac{10-1}{12.6} \right]$$

$$TG = 19.9 + 0.3 = 20.2 \text{ dB above } 1\,\mu V/m$$

$$TG = 10.2\,\mu V/m.$$